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Richard B. Engdahl, Jacques Dartoy & Philip Beltz

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505 King Avenue
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The evaluation, which consists of two volumes of text and 15 trip reports, analyzes the experiences of the Europeans with waste to energy systems. The text is a compilation of the data obtained during visits to 15 major European refuse fired energy systems and visits to systems vendors, government agencies and other plants.

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EUROPEAN REFUSE FIRED ENERGY SYSTEMS

Evaluation of Design Practices

Volume 1

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U.S. ENVIRONMENTAL PROTECTION AGENCY
1979

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DIGEST AND MAJOR CONCLUSIONS

The major conclusion is that the mass burning of unprepared municipal solid waste in heat recovery boilers is well established, and can be a technically reliable, environmentally acceptable and economic solution to the problem of disposal of solid wastes. It is not as cheap as use of currently available landfills. However, when the cost is considered of upgrading current landfills and established new landfills in accordance with the Resource Conservation and Recovery Act (RCRA) provisions, these mass burning waste-to-energy systems are expected to compare more economically with true sanitary landfills.

Another significant conclusion is that many European areas are moving steadily in the direction of Energy and Environmental Parks that often include refuse burning, animal rendering, electricity production, sewage disposal, industrial steam generation, hot water district heating, etc.

A surprising conclusion is that over a wide range of plant sizes from 200 to 1,600 tons per day there appears to be little significant economy of scale. The data suggests that the net operating and owning costs for plants within these size ranges and with the same plant configurations normalized for inflation, exchange rates, site costs and so forth fall in the range of $6 to $36 per ton with the average about $16. While this range appears significant, the factors that cause the variation are not size related as much as previously thought.

A major impetus for the development in European of waste-to-energy systems was the finding that it was possible to control air pollution from the burning of wastes by cooling the dirty exhaust gases. Concurrent with this influence was the disenchantment with old leaching landfills as a long-range solution to the solid waste problem in very crowded countries.

The cost of alternative energy forms (coal, oil, gas) will become even more important to the development of refuse-fired energy systems. Yet the total potential energy in the wastes of a modern community will be less than a tenth of its total energy demand. Hence, waste-to-energy alone cannot be expected to become a major energy source.

Many conditions in the U.S. have been different, hence waste-to-energy has not advanced as rapidly as in Europe. Some of these differences will continue, but we are moving rapidly to similar conditions in most of our metropolitan areas. Hence the lessons that have been larned in 80 years of refuse fired energy plant (RFEP) experience in Europe can be effectively utilized by many U.S. communities. We hope that this series of reports will be of help to community officials and technologists in applying those lessons to U.S. environmental and energy problems.

PREFACE

These documents are a two volume evaluation of European refuse - fired energy systems design practices, which is a condensation and analysis of trip reports describing visits in 1977 to fifteen (15) European refuse fired steam and hot water generators. Interspersed are comments about another fifteen (15) plants for which official trip reports were not prepared, i.e., a total of thirty (30) resource recovery plants were visited. In addition, visits to five (5) federal environmental protection agencies have provided additional insight to solid waste management trends, legislation and perspectives on resource recovery technologies.

The material in the reports describing the visits to the fifteen (15) plants has been reviewed by the European system vendors and their respective American licensees. The two volume evaluation report has also been reviewed, but the comments of the various reviewers has not been incorporated in the text. Rather, their comments are presented in toto in the appendix to Volume II.

Battelle Columbus Laboratories maintains ultimate responsibility for report content. The opinions set forth in this report are those of the Battelle staff members and are not to be considered EPA policy. There may be some minor errors and certainly differences of opinion in the report, but these do not take away from the usefullness of the document.

The intent of the report is to provide decision making information. The reader is thus cautioned against believing that there is enough information to design a system. Some proprietary information has been deleted at the request of vendors. While the contents are detailed, they represent only the tip of the iceberg of knowledge necessary to develop a reliable, economical and environmentally beneficial system.

The selection of particular plants to visit was made by Battelle, the American licensees, the European grate manufacturers, and EPA. Purposely, the sampling is skewed to the "better" plants that are models of what the parties would like to develop in America. Some plants were selected because many features evolved at the plant. Others were chosen because of strong American interest in co-disposal of refuse and sewage sludge.

The two volumes plus the trip reports for the 15 European plants are available through the National Technical Information Source, Springfield, Virginia, 22161. Of the 17 volumes, only the Executive Summary has been prepared for wide distribution.

ACKNOWLEDGEMENTS

The project owes much of its success to the many European vendors, plant personnel, city officials, and European environmental protection agency staff who opened up so fully to the visiting Battelle team. It is an established fact that Europe is far advanced over America in commercialization of the refuse-fired, steam- and hot-water generation technology. This fact and the accompanying pride of accomplishment are likely causes for the excellent cooperation we received and outpouring of valuable information from visited European professionals. Frankly, the amount of information freely provided has amazed and challenged these researchers. The authors hope that we have been able to summarize accurately the data provided.

Our appreciation is also extended to the EPA staff of David Sussman--Project Officer, Steve Levy--Program Manager, and to Steve Lingle--Chief of Technology and Markets Branch.

The detailed listing of the many names, organizations and addresses is to be found in Part II. Each person and organization should realize that they have contributed to the advancement of solid waste management in America.

ORGANIZATION OF REPORT

The report consists of twenty three chapters in two volumes. Chapter A, The Executive Summary and Chapter B, The Inventory of Waste to Energy Systems are being published by the Office of Solid Waste for wide distribution. The Executive Summary and Inventory are also included in the two volume set, which is available through NTIS.

Volume I contains information relating to the implementation of the systems, whereas Volume II contains technical information about the units themselves. The paragraphs in the Executive Summary follow the same format.

INTRODUCTION

Background

Since 1896 (in Hamburg, West Germany), communities have been converting municipal refuse into electricity and other energy uses. Many of the early systems were batch operated with manual refuse feeding and manual ash removal.

Between the two world wars, many developments were made in refuse handling in general and grate systems in particular. There were also major improvements in the refractory wall furnaces and the separate waste heat boilers.

Many of the systems were destroyed during World War II. The evolution of the water-tube wall integrated furnace/boiler began in the 1950's. It paralleled developments 30 years earlier in the water tube walled pulverized, coal-fired boiler/furnace.

More precisely, the world's first integrated water-tube wall furnace/boiler began operation at Berne, Switzerland in 1954. Two 100 tonne per day units produced steam to make electricity. Some steam was sent to industry. Other steam was sent to a steam-to-hot-water heat exchanger. This hot water was then sent to the local district heating network. This original Von Roll plant continues to operate 25 years later in 1979.

The business of designing and building those and other wate-to-energy systems has grown exponentially since 1954. Now we can point to at least 522 places in the world where energy conservation objectives are met by recovering values.

Objective

The general objective of the project was to gather information about European waste-to-energy practice and to interpret this experience as it may be commercially practicable in the U.S. The subobjectives are listed as follows:

1. Report on actual technical, economic, environmental, and social experience in application of the European technologies of (1) integrated water tube wall furnace/boiler and (2) refractory wall furnace/waste heat boiler.
2. Aid American decision makers and engineers in utilization of the successful experience of their European counterparts.
3. Describe in a technical manner how successful operations are achieved and how unsuccessful operations are avoided.
4. Prepare Report -- "Evaluation of European Refuse-Fired Energy Systems Design Practices".
5. Prepare 15 Trip Reports describing systems visited.

Scope

The geographic scope as clearly indicated in the title is Europe. However, there will be frequent references to systems in America and comments about other countries. For example, Japan has the greatest number of refuse-fired energy generating units (43) of any country in the world; with an installed capacity of 27,000 tons per day.

Several solid waste management topics are discussed. Some are beyond the original contract scope but are presented to give the reader a better perspective of the total picture. The refuse to energy systems are as follows:

- Water-tube wall furnace/integrated boiler
- Refractory wall furnace/waste heat boiler
- Vertical shaft pyrolysis

Other types include:

- Refuse transfer stations
- Hazardous waste transfer stations
- Landfilling
- Composting
- Rendering
- Pathological incineration
- Waste water treatment
- Environmental, Energy and Industrial Parks.

The chronological scope begins in 1876 when the first refuse to electricity system was built in Hamburg, West Germany.

The scope of processing capacity described ranges from the 120 tonne (132 ton) per day single line facility at Werdenberg-Liechtenstein to the large 1,630 tonne (1,793 ton) per day four line system at Paris: Issy-les-Moulineaux. The energy uses scope includes use of hot air, hot water, superheated water, steam, superheated steam and electricity.

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EXECUTIVE SUMMARY

Development of the Refuse Fired Energy Generator Technology

Producing and utilizing energy from refuse combustion goes back many years. One early account is the 1896 refuse to electricity and industrial steam plant in Hamburg, Germany located on Rohrstrasse. There were other turn of the century refuse to energy plants located at Paris and Zurich.

But the Europeans were not the only people active in this field. There were in New York City several refuse fired steam generators as recorded in a Saturday Evening Post article.*

"In 1902 the simple destruction of this material was begun at an incinerator located at Forty-seventh Street and the North River. This simple destruction is satisfactory from both a financial and a sanitary point of view. Very soon an attempt was made to utilize the heat derived from this combustion for purposes of steaming, and, in 1903, a small electrical plant was installed for the lighting of one of the stables of the deportment and of the docks and piers in that vicinity.

In 1905, the idea of economically using rubbish wastes to light municipal structures and buildings, being beyond the experimental stage, a plant was constructed beneath the Williamsburg Bridge, (on Delancey Street) where daily 1050 cubic yards of light refuse are destroyed. During the night, the heat is used to generate electricity to light The Williamsburg Bridge ... The material handled at the Delancey Street plant is about one-fifth of the total output of the boroughs of Manhattan and the Bronx."

---

* The Waste of a Great City: The New Alchemy That Transmutes Refuse Into Heat, Light, Power and Property; The Saturday Evening Post; December 15, 1906.

The above points out one fact. The first systems were sophisticated enough to produce electricity. They were not just simple hot air generators. The early units were refractory walled and thus the steam quality (temperature and pressure) was limited.

During the period from 1910 through 1945, there were many improvements to the overall systems and to the art of boiler making. Also, during this time there was increasing concern about the wastefulness of using valuable land for unsightly landfills. There was also an occasional increase in concern about landfill leachate effects on ground water contamination.

Then in the late 1940's and 1950's, vendors (primarily Von Roll in Zurich) began to develop ways to take more energy out of the combustion gases. This effort was spearheaded by Mr. R. Tanner formerly of Von Roll. Some consider him one of the originator's of the modern-day water-tube wall refuse incinerator/boiler. Basically he applied to refuse combustion what he and others had learned about coal combustion in water-tube wall units. As explained later in the Boiler Section, the "water-tube wall furnace/boiler" has the refuse combustion section surrounded by vertical or sloping steel tubes in parallel which absorb the heat and thus generate a major fraction of the total steam produced. This increases efficiency and allows a much higher quality steam to be produced.

By 1965, European and Japanese citizens and government officials were becoming concerned about the long-term effects of landfills. These concerns led many cities to choose refuse burning. They were, and still are, willing to pay a premium price for refuse burning over landfilling. In many cases the refuse burning option is two, three or four times as expensive as landfilling.

The Japanese, since 1965, have become increasingly conscious of what is put into close-in fishing waters off the Japanese coast. Their diet depends so heavily on saltwater fish. High concentrations of heavy metals and organics were found in coastal waters. Industry, municipal sewage plants and landfills were blamed for these concentrations.

In addition to landfills on normal land, the Japanese have long reclaimed the sea with trash. In 1974 one of the authors spent an afternoon observing the 180 acre "Dream Island" in the Tokyo Bay. Pilings had been driven and household refuse and construction debris were then dumped in. Now after many years, the waste has settled and several buildings have been constructed, including the attractive 1800 ton per day Koto incinerator built by Takuma. However, sea filling with household refuse is no longer permitted in the sea. Instead Japan has become the world's most active builder of refuse fired steam generators--primarily due to their fear of landfill or seafill leachate effects.

Prompted by concern for leachate and the scarcity of land, many European countries and cities had refuse burning construction programs from 1960 to 1973. Actually by the time that the Arab Oil Embargo occurred in 1973, some of the countries were nearly saturated with refuse burning plants. The effect of doubling or quadrupling of energy prices was not very noticeable on new orders.

These authors have concluded that energy considerations have never been, and are not now, the driving force leading to construction of most refuse energy systems. Cities build refuse fired energy systems because they fear the long-term effects of landfill leachate, they perceive a shortage of land and officials are frustrated by the unpleasantries of locating landfill sites every several years. Imported oil prices would have to rise dramatically before the basic motivation for resource recovery changes from concerns about landfilling to concerns about energy.

The next force on the development was pressure to clean the atmosphere. It is hard to know exactly when this pressure began building, but it was well noticed during the 1960's. Air pollution control equipment was needed to capture most of the flyash released by incineration. Such air cleaning equipment would deteriorate rapidly if the very hot flue gases from incineration were passed through them. Thus the flue gases had to be cooled.

Three methods could be used for cooling: (1) water spray, (2) massive air dilution and (3) heat recovery boiler. There were communities with refuse but not a sufficiently concentrated energy demand to make energy production realistic. Hence many systems were built with only a spray cooling chamber ahead of the: (1) baghouse, (2) scrubber, or (3) electrostatic precipitator. Unfortunately the moisture inherent in such water spray systems would remain in the ductwork and the air cleaning device when the unit was shut down. This often caused excessive "dew point" corrosion. Air dilution devices are not usually favored because of the need for vary large and expensive air cleaning equipment. For these reasons the heat recovery boiler has become the predominant method used for cooling the gases in European refuse-burning plants.

Description of Communities Visited

As previously explained in the Scope section, this report is devoted to both (1) the refractory wall furnace with waste heat boiler often producing hot water for district heating and (2) the water tube wall integrated furnace/boiler normally producing steam for electrical production, industrial uses and steam or hot water for district heating.

Locations Visited

In total, 30 refuse fired energy plants were visited. Of these, 15 were examined in detail (See Table A-1a). These 15 are described in separately bound trip reports available from the U.S. National Technical

TABLE A-1a. SUMMARY DATA ON THE 15 SURVEYED PLANTS VISITED BY BATTELLE FOR THE U.S. EPA PROJECT ON WASTE-TO-ENERGY (1977 Visits)

MAJOR VISITS (15)

Visit Date	Plant Name	City	Manager	Mfr.	Start Up Date	No. Units and Design Cap. Mt/h	Daily Design Mt.	Actual 1976 Mt/Year
May 3-5	Werdenberg, Switzerland	Buchs	Giger	W&E	1974	1 x 5	120	26,018
May 9-11	Baden-Brugg, Switzerland	Turgi	Leudi	W&E	1970	2 x 4	200	41,693
May 17-18, 24	Dusseldorf, Germany	Duessdf.	Thoeman	VKW	1965	4 x 10.1 x12.5	1260	297,359
May 20, 23	Krefeld, Germany	Krefeld	Korbel	VKW	1976	2 x 12	560	114,000
May 22, 26	Wuppertal, Germany	Wuppt.	Bucholz (Temelli)	VKW	1/76	4 x 15	1440	178,000
June 1, 3	Issy-le-Moulneaux, Fr.	Paris	Aneaue (Cherdo)	Martin	1965	4 x 17	1635	588,904
June 8-10	Hagenholz, Sw.	Zurich	Baltensperger	Martin	7/73	1 x 21	380	223,595
June 13-15	Stellinger-Moor, Gmy.	Hamburg	Arndt	Martin	11/73	2 x 24	1180	420,680
Sep. 14-16	The Hague, N.	Hague	Postma	V-R	1968	4 x 15	1440	229,000
Sep. 19-20	Dieppe, Fr.[a]	Dieppe	Fossey	V-R	1974	2 x 2.8	134	14,892
Sep. 21	Deauville, Fr.[a]	Deavle.	Hearvee	V-R	1976	2 x 2.8	134	--
Sep. 22-23	Gothenberg, Switzerland	Gothbg.	Rudlinger	B&S	1970	3 x12.5	900	242,536
Sep. 26-27	Uppsala, Switzerland	Uppsala	Berg	B&S	1970	1 x 5	120	52,040
Sep. 28-29	Horsens, DK	Horsens	Larsen	B&S	1974	1 x 5	120	18,909
Oct. 4	Cophgn.- Amager Denmark	Cophgn.	Nilsson	Volund	1970	3 x 12	864	255,000
Oct. 5	Cophgn.- West Denmark	Cophgn.	Jeneslev	Volund	1970	3 x 12	864	234,230

[a] Plants 70 km apart - one trip report

Information Service (N.T.I.S.). Key energy information is shown in Table A-1.b. The other 15 plants are listed with identifying features in Table A- 2. Comments about these systems are interspersed throughout the report. A third source of information was the visits to 5 Federal environmental protection agencies. These agencies are listed in Table A-4 along with other local government, manufacturer and consultant offices.

We wish to express our deepest appreciation to our hosts, men of expertise in converting refuse to energy, for their generous and skilled assistance.

Background information about the communities visited is necessary for better understanding of historical solid waste practices, system development, energy utilization, system performance, etc.

Each community is described in terms of its waste generation areas, terrain, natural and manmade boundaries, relationship among neighboring communities, population, and key employment activities that influence waste composition.

Collection Areas and Jurisdictions

The collection areas and radii are shown in Table A-4. Note that Werdenberg-Liechtenstein has the greatest area and longest radius. Yet this plant has the smallest capacity at 120 tonnes (132 tons) per day. Conversely the largest capacity plant, Paris:Issy, has the smallest collection area and radius.

Numbers of separate jurisdictions associated with each plant are also shown in the table. A point to be observed is that, in most of these systems, it is necessary to obtain waste from many jurisdictions to maintain or improve economics of scale, once the plant has been built. Later, in the Economics section, we will argue that (with the exception of very small plants) there are very few economics of scale taken advantage of in the designs of refuse fired steam generators.

Terrain, Natural and Manmade Boundaries, Neighborhoods

The sampling of plants covers the many geographical conditions to be found in Europe.

Population

The most relevant population figure for plant designers is that for the waste shed area served. As shown in this same Table A-4, the waste shed population numbers range from 48,000 in Dieppe to 837,286 in Duesseldorf and even greater at Paris. Population, waste generation rates, collection area are all related to system economics. At the low end, the plant must be big enough to achieve some degree of efficiency to pay for fixed costs. However at the high end, costs of transporting refuse limit the maximum population served in a waste shed.

Separable Waste Streams

This report is concerned not only with the burning of refuse, but also with the handling of all waste materials within the same facility. Many of the observed facilities include three or more separate waste-stream

TABLE A-1b. SUMMARY DATA ON THE 15 SURVEYED PLANTS VISITED BY BATTELLE FOR THE U.S. EPA PROJECT ON WASTE-TO-ENERGY (1977) Visits) (Continued)

MAJOR VISITS (15)

Visit Date	Plant Name	Design Steam Cap. Mt/h Nom.	Design Steam Cap. Mt/h Max.	Evapor. stm/ref.	Rate year	Steam Press atm.	Steam Press psig	Steam Temp. C	Steam Temp. F	Max. Elec. Gen. Capac. MW
May 3-5	Werdenberg, Switzerland	12	16	2.34	1976	39	570	395	740	0.85
May 9-11	Baden-Brugg, Switzerland	11.4	-	2.26	1976	40	590	400	752	5.2
May 17-18, 24	Dusseldorf, Germany	89	94	2.08	1976	80	1160	500	932	50
May 20, 23	Krefeld, Germany	42	-	-	-	23	-	376	700	2.8
May 22, 26	Wappertal, Germany	202	-	-	-	29	425	340	644	40
June 1, 3	Issy-le-Moulneaux, Fr.	160	168	-	-	53	780	410	770	25
June 8-10	Hagenholz, Switzerland	38	-	2.41	1976	45	660	420	788	12
June 13-15	Stellinger-Moor, Germany	80	-	-	-	52	764	410	770	16.5
Sep. 14-16	The Hague, N.	150	-	1.98	1976	40	566	425	797	23
Sep. 19-20	Dieppe, Fr.[a]	15	-	-	-	16	217	180	356	0
Sep. 21	Deauville, Fr.[a]	15	-	-	-	16	217	180	356	0
Sep. 22-23	Gothenberg, Switzerland	157.5	-	3.18	1976	22	309	214	417	0
Sep. 26-27	Uppsala, Switzerland	40	-	2.44	1975	15	200	138	280	0
Sep. 28-29	Horsens, DK	HW[b]	-	-	-	-	-	-	-	0
Oct. 4	Cophgn.- Amager Denmark	HW	-	-	-	-	-	-	-	0
Oct. 5	Cophgn.- West Denmark	HW	-	-	-	-	-	-	-	0

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[a] Plants 70 km apart - one trip report

[b] Hot Water generation only

TABLE A-2 . MINOR VISITS (15) - DATE, LOCATION, MANUFACTURER, REASONS AND, COMMENTS RELATED TO BATTELLE'S BRIEF VISIT TO 15 OTHER WASTE-TO-ENERGY FACILITIES*

Date (1977)	City, Country	Manufacturer	Reason for Visit or Comments
5/5	Oberthurgau, Switzerland	Widmer & Ernst	Between official visits
5/5	Bazenheid, Switzerland	Martin	Between official visits
5/6	Biel, Switzerland	KKK, Dano	Exceptionally integrated compost plant
5/6	Neuchatel, Switzerland	Widmer & Ernst	Only baghouse in Europe on incinerator
5/7	Trimmis, Switzerland	Widmer & Ernst	Saturday visit on leisure
5/12	Furth, W. Germany	Widmer & Ernst	Scrubber retrofit under construction
5/12	Ingolstadt, W. Germany	Widmer & Ernst	New and latest scrubber under construction, co-disposal
5/16	Cologne, W. Germany	Keller Peukert(VKW)	Hospital waste, example of small system
6/7	Luxemborg, Luxemborg	Martin	One of Martin's newest systems and is next to Torrax
6/8	Luxemborg, Luxemborg	Torrax	High EPA and American interest
9/21	Deauville, France	Von Roll	Newer plant design could augment Dieppe report
9/30	Aarhus, Denmark	Brunn & Sorensen	Newer plant design could augmet Horsen report
10/6	Roskilde, Denmark	Volund	Volund plant without rotary Kiln
10/7	Kiel, W. Germany	VKW	Oldest working RFSG scrubber in Europe at the time
10/14	Emmenspitz, Switzerland	Von Roll	Newest V.R. system, vendor strongly urged

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* Separate Trip Reports were not prepared for these facilities. However, many are referred to in other Trip Reports and the Evaluation Report itself.

TABLE A-3. DESCRIPTION OF 19 OFFICES VISITED BY BATTELLE WHILE ON TOUR OF EUROPEAN WASTE-TO-ENERGY FACILITIES

Date	Organization	Location	Host	Vendor	Activity
May 5	Eawag-Empa	Dubendorf, (Sw)	--	--	Swiss testing laboratory
May 10	Widmer & Ernst, Wettingen	Wettingen, (Sw)	Wuttrich	W&E	Corporate offices
May 13	Bav. Umweltschurzant	Munich, (Gmy)	Fuhrmaier	--	Regional German EPA offices
May 16	VKW Boiler Plant	Duesseldorf, (Gmy)	Schlottman	VKW	Manufacturing plant
June 2	Min. de Qual. de Vie & Env.	Paris, (Fr)	Collardeau	--	French national EPA
June 2,3	Trait. Ind. des Residus Urban	Paris, (Fr)	Defeche	--	Office managing 4 refuse plants in Paris
June 2	Office of City Cleansing	Paris, (Fr)	Monterrat	--	City of Paris collection dep.
June 10	European Environmental Entprs.	Zurich, (Sw)	Tanner	--	Developer of water tube wall RFSG
June 14	Hamburg Stadtreinieung	Hamburg, (Gmy)	Grosstueck	--	Office Managing several solid waste coll. dis. oper.
May 25	VKW Headquarters	Duesseldorf, (Gmy)	Mutke	VKW	Corporate officers
June 16	Martin Headquarters	Munich, (Gmy)	Martin	Martin	Corporate officers
Sept. 12	Widmer & Ernst	Zurich, (Sw)	Ernst, Nold	W&E	Corporate officers
Sept. 13	Von Roll	Zurich, (Sw)	Dirilgen, Kehoe	VR	Corporate officers
Sept. 16	Dutch EPA (MVVM)	Leidschendam, (Nd)	Van Wijk	--	Netherlands Federal EPA
Sept. 28/30	Bruun & Sorensen	Aarhus, (Dk)	Host, Sowdergaard	B&S	Corporate officers
Oct. 3,5	Volund	Copenhagen, (Dk)	Silva-Pinto	Volund	Corporate officers
Oct. 6	Danish Environ. Prot. Agency	Copenhagen, (Dk)	Mortensen	--	Denmark's Federal EPA
Oct. 7	Von Roll	Zurich, (Sw)	Sarasch	--	Arrange visit to Emmenspitz
Oct. 8	Kunstler & Koch	Zurich, (Sw)	Kunstler	--	Kunstler corporate office

TABLE A-4. COLLECTION AREAS, RADIUS, JURISDICTIONS AND POPULATION

Trip	City	Area		Collection Radius		Separate Jurisdictions	Waste Shed
		km²	miles²	km	miles	Number	Population
1	Werdenberg-Liechtenstein, Switzerland	900	345	33	20	28	76,685
2	Baden-Brugg, Switzerland	100	38	--	--	56	140,000
3	Duesseldorf, W. Germany					32	837,286
4	Wuppertal, W. Germany	100	38	--	--	--	444,000
5	Krefeld, W. Germany	--	--	--	--	--	350,000 (refuse) 600,000 (sludge)
6	Paris:Issy, France	--	--	--	--	55[a]	1,635,000[c]
7	Hamburg:Stellinger-Moor, W. Germany	--	--	--	--	--	500,000
8	Zurich:Hagenholz, Switzerland	--	--	--	--	--	560,000
9	The Hague, The Netherlands	--	--	15	9.3	--	550,000
10	Dieppe, France	--	--	12	7	--	48,000[b]
11	Gothenburg, Sweden	1,000	386			--	670,000
12	Uppsala, Sweden	--	--	--	--	9	--
13	Horsens, Denmark	--	--	--	--	7	64,000
14	Copenhagen:Amager, Denmark	--	--	--	--	--	620,000
15	Copenhagen:West, Denmark	--	--	--	--	12	620,000

(a) Sending waste to three large refuse plants

(b) Population increases in the summer, so that 48,000 is a year-around average.

(c) Estimate

systems. Table A-5 summarizes waste streams associated with each facility that are treated independently from the main refuse burning waste stream.

There are usually multiple and separate waste streams flowing into the same property. Perhaps due to socialism or age of the community, there is a greater sense of environmental planning and physical integration among system modules. There are many examples of synergistic benefits experienced by combining not only environmental modules (refuse burning, waste-water treatment, animal rendering, etc.) but also the energy modules (district heating, electricity generation, etc.) within the same facility. Each waste stream category is summarized below.

Household, Commercial and Light Industrial Refuse (i.e. the Main Waste Stream)

The focus of the project is to examine in detail the treatment of the household, commercial, and light industrial waste stream. All 15 facilities process this type of mixed waste stream. Refuse collection, transfer stations, and physical and chemical composition are discussed in detail.

Bulky and Large Industrial Wastes

Eight of the 15 facilities have shears to reduce bulky and large industrial waste to 1 meter (3 feet) or less. Only Duesseldorf has a shredder; it is seldom used.

The large hoppers and furnaces in plants built by Martin will accept bulky waste of reasonable size. None of the Martin plants visited had shears or shredders. However, at each Martin plant, there was encouragement for acceptance of only household, commercial, and light industrial waste. The few large pieces are broken in the pit by a falling grab bucket.

At Copenhagen: Amager the bulky waste is taken to the crusher transfer station adjoining the refuse-burning plant. Reasonably sized construction debris and other noncombustible material is packed directly into transfer trailers. These noncombustible loads are then taken to a landfill. However, bulky combustible materials first pass through a shredder before being compacted into a trailer. The combustible loads are then taken a short distance to the refuse-burning plant.

Wastewater and Sewage Sludge

Five of the facilities have wastewater treatment plants coterminous with the refuse burning plant. Sanitary services in Europe are often centralized and well coordinated. In four of the 15 plants, the energy value in refuse is utilized to drive off moisture in the sludge. Three of these plants then burn the dried sludge. In total, the Battelle staff visited 7 such co-disposal systems.

Source Separation

Source separation is practiced sporadically in Europe as it is in the U.S. Its success varies depending on markets, transportation distance,

TABLE A-5. SEPARABLE WASTE STREAMS IDENTIFIABLE WITHIN THE GATES OF REFUSE-FIRED ENERGY PLANTS

	TOTAL	Werdenberg-Liechtenstein	Baden-Brugg	Duesseldorf	Wuppertal	Krefeld	Paris:Issy	Hamburg:Stellinger-Moor	Zurich:Hagenholz	The Hague	Dieppe (and Deauville)	Gothenburg	Uppsala	Horsens	Copenhagen:Amager	Copenhagen:West
Household, Commercial & Light Industrial	15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bulky & Large Industrial	8	X	X	X	X	X				X		X			X	
Waste Water	5	X	X			X					X			X		
Sewage Sludge	6	X	X			X					X			X		X
Source and Front-End Separation																
Paper & Cardboard	1															X
Iron, Steel, & White Goods	3					X				X						X
Bottles	2									X						X
Copper in Motors	1									X						
Tires	1									X						
Used Crank Case Oil	3		X						X					X		
Waste Oil Emulsions	3		X						X					X		
Oil Sludges	2								X					X		
Waste Solvents	2								X					X		
Industrial Chemicals	3								X					X	X	
Hazardous Wastes	4		X						X					X	X	
Dextrose Sludge	1												X			
Animal Waste	4	X							X			X	X			
Street Sweepings	1									X						
Construction Debris	3									X				X	X	
Demolition Debris	2									X				X		
Ash	1													X		
Junk Cars	1													X		

price, and conservation attitudes. Two source separation programs were observed in Denmark.

Near Copenhagen:West, several recycling centers are located at shopping centers. In addition, one of the recycling centers is located at the entrance to the West plant. Homeowners and businessmen who appreciate the need for recycling can drive their own vehicles to the refuse burning plant and can then place their discarded items into any of several containers.

We were told that these and other source separation programs remove no more than 10 to 15 percent of the potential heat value from the waste-to-energy system.

Zurich has just started three voluntary recycling centers for glass, cans, and waste paper. The city has had seven centers for collection of used crankcase oil. Garages and private individuals bring their waste oil to the centers. However, no money changes hands.

At Baden-Brugg, about 35 percent of the waste glass generated is recycled through a residential pickup system using special containers.

Around Werdenberg-Liechtenstein, there are some shopping center-type recycling centers where people can bring newspapers, bottles, and cans. Color-sorted glass can be sold for 60 S.Fr per tonne ($26.40 per ton) while noncolor sorted glass can be sold at 40 S.Fr. per tonne ($17.60 per ton) (at the 1977 rate of 2.27 S.Fr./$).

Front-End Separation

The most elaborate front-end separation system observed during the 30 visits was at The Hague. Private haulers often bring in a combination load on flat bed or dump trucks. The white goods are unloaded and then the other bulky combustibles are put into the pit provided to private haulers. A workman then attempts to remove the copper-rich motors. Rubber tires are stacked. Then the shovel loader crumples and smashes the stove or refrigerator for better storage and handling.

The only shredder observed among all of the 15 plants was at Duesseldorf. The Hazemag shredder was down on both of Battelle's visits in 1976 and 1977. However, because ferrous metal is not even separated, this can not really be classified as a front-end separation system. This shredder suffered a major explosion in 1975.

At Uppsala, there is a single bin for ferrous materials in a corner of the tipping floor.

The only real "American type front-end pre-incineration system" operating daily on a full scale is at Birmingham, England. It was inspired by U.S. EPA's demonstration project in St. Louis, Missouri. Battelle staff did not visit this Imperial Metal Industries (IMI) facility.

Waste Oils and Solvents

Waste crankcase oil, oil emulsions, oil sludges, and solvents are processed at two of the facilities. At Baden-Brugg, the oils are carefully processed in a decanting facility. Nearby at Zurich:Hagenholz, waste oils are decanted and then mixed with more volatile solvents.

Industrial Chemicals and Hazardous Wastes

There is a distinct difference in attitude in Europe compared to that in the U.S. with regard to the public sector's responsibility in handling hazardous waste. One-third of the 15 facilities have on the same or neighboring properties a capability to handle industrial chemical or hazardous wastes. At Baden-Brugg, a neighboring closed compost plant has been leased by a private company (Daester-Fairtec A.G.) and has been converted into an inorganic heavy metals hazardous waste processing center. This plant has several independent processing lines using ion exchange, evaporation, activated carbon, filtering, decontamination, and neutralization.

The Zurich:Hagenholz plant receives hazardous wastes from local industry and transfers it to the appropriate hazardous waste treatment centers. Some goes to Baden-Brugg and some will go to the elaborate Geneva County facility being built at les Chenneviers.

In Uppsala, Sweden, the local pharmaceutical company produces a dextrose sludge. This material is fed to a special hazardous waste incinerator adjoining the refuse-burning plant. Off-gases are sent to the hot-air-mixing chamber just after the refuse burner for hydrocarbon destruction.

Denmark now carefully controls all hazardous wastes. All industrial generators are required to take their waste to an approved hazardous waste receiving station. When enough waste has been collected, it is transported, usually by rail to Nyborg, Denmark for ultimate processing. Hazardous waste collection centers were observed at Horsens and Copenhagen:Amager.

Animal Waste

Animal waste is received at four facilities. A trip highlight was to see the new rendering plant at Zurich:Hagenholz. Animal carcasses, butcher shop trimmings, etc. are rendered into flesh meal, animal feed, and soap. This new plant was purposely located next to the refuse burning plant. The rendering plant's ventilation system was carefully designed to collect odoriferous room air from the plant. The air is sent from the rendering plant to the refuse burning plant where it is injected directly into the refuse furnace as high pressure secondary air. This is one example where the refuse fired steam generator serves as an afterburner.

Street Sweepings

The only facility observed to handle street sweepings as a separately controlled waste is at The Hague. That was only for weighing at a common scale before landfilling.

Construction, Demolition Debris, and Ash

Construction and demolition debris is not put into the refuse burners to any extent. Ash, however, was a key component of municipal refuse entering the incinerator plants until about 20-30 years ago when homeowners switched to oil and gas fuels. The lack of this inert ash has allowed the average heating values of refuse to rise. High temperature corrosion in established furnaces was the result in many furnaces.

Construction debris is brought to The Hague facility and placed directly into a detachable container for transport to a landfill.

The Horsens plant is located on top of the old landfill and adjoining the still active landfill jutting out into the sea. Thus, the total facility consumes locally generated construction and demolition debris and ash.

Construction debris in southeast Copenhagen is taken to the transfer station located 100 meters from the Copenhagen:Amager refuse burning plant. It is then trucked away to Uggelose landfill northwest of Copenhagen or to an Amager Island seafill reclamation site.

Junk Automobiles

Some of the Horsens community-owned land adjacent to the plant has been leased to a car and truck junk dealer which is located adjoining the refuse burning plant.

Refuse Collection and Transfer Stations

The European pattern of collection and transfer has many similarities to that of North America. Generally speaking, there is more collection by the public sector, occasional labor representation in management functions, and occasional computerized systems for physical control and fiscal billing. The homeowner cost assessment methods are quite varied.

Household Containers

There is a clear trend away from the open top metal refuse container in favor of rubber, plastic or paper containers. An integrated program of collection truck purchase along with purchase of standardized rubber or plastic containers was observed several times in Central Europe. Several other systems used standard sized paper sacks that could be collected by a flat bed truck rather than by a more expensive compactor truck. Other systems use polyethelene sacks. Most high quality steam production facilities discourage PVC container sacks due to the corrosive effects of the chlorides formed in combustion.

Collecting Organization

Generally speaking, there is more public and less private collection in Europe. However, as in the U.S., this varies widely from city to city.

Many European public collecting organizations permit representatives from labor to participate in management functions. This, in part, has contributed to the success of two industrial engineered collector control and payment incentive systems at Hamburg and Copenhagen:Amager.

Collection Costs

Worldwide, collection costs are 70 to 90 percent of the total cost of both collection and disposal. At most facilities, only the total is accurately known because that is the amount billed to citizens and thus the better known figure. Costs range from $25 to $90 per year per household as a solid waste management charge to the citizens.

Assessment Methods

The methods for assessing collection (and disposal) costs vary widely. Some systems serve so many cities that a clear assessment pattern was not available. The Hamburg and Wuppertal plants obtain revenue from household rental of standardized rubber containers. At Horsens, paper sacks are purchased by homeowners. Paris assesses solid waste costs in proportion to real estate taxes. Dieppe, however, assesses in proportion to metered water service. Probably the most accurate assessment comes from Renholdnings Selskabet (Society for Waste Collection) in Copenhagen. Charges are set based on container volume, steps walked, and stairs climbed.

Vehicles

European vehicles, generally, have similar features, options and size ranges as in the U.S. However, due to smaller and winding streets, the average vehicle size is smaller. Paris uses a few electric trucks. Gothenburg uses cylindrical-bodied transfer trailers not seen in America.

Collecting Times

Trucks make one to four trips per day depending on geography, average haul distance, and labor agreements. Official hours are often 8 per day. However, many actually work only 5,6 or 7 hours per day. In Paris, workers collect refuse for about 4 hours and then sweep city streets for another 4 hours.

Most workers collect 5 days per week. Some private haulers collect 5 1/2 days. Paris provides 7 day per week pickup of restaurant garbage.

Homeowners have their refuse picked up once or twice per week.

Homeowner Deliveries to Refuse Burning Plant

Many plants place detachable containers near the entrance to the facility so that cars, trailers, pick up trucks, etc, can unload without interrupting larger vehicle deliveries. In several countries, citizens are prohibited from direct dumping into pits.

Industrial and Bulky Waste Collection Activity Affecting Resource Recovery

Some refuse burning facilities will take only household refuse. Refuse burning and energy production is greatly simplified if high calorie-containing industrial and bulky waste is excluded.

Some plants accept such waste because incineration is the desired disposal alternative and/or because the energy network needs the energy from this waste. Then, the plant manager and staff may have to put forth the extra effort. Care must be exerted to not overheat the unit if not originally designed for the "hotter" industrial waste.

Transfer Stations

Transfer stations are increasingly popular in Europe as (1) economies of scale require more waste to be consumed at one location and (2) there is a desire to reduce highway travel time and collection costs.

In Paris, the Romainville incinerator was converted to a transfer station. Refuse is transferred to Issy for combustion.

At Gothenburg, five transfer stations compact and 30 trailers bring refuse to the Savenas refuse fired steam generator.

Copenhagen:Amager's concept is quite different. The transfer station is located next to the refuse burner. Both are located near the populated downtown. Bulky combustibles are shredded and transferred 330 meters (100 yards) to the refuse burner. Noncombustible waste is simply transferred to a distant landfill or seafilled.

There are plans at Uppsala to put a transfer station in a distant city so that more energy-containing waste can be gathered and converted to needed district heating hot water at Uppsala.

A transfer station in Horsens is one of 20 that collect industrial and hazardous waste for transport to Nyborg, Denmark. The Danes are leaders in regional government hazardous waste collection and controlled disposal.

Because European furnace grates are not designed for shredded material, there is only a moderate amount of shredding at a transfer station prior to landfill. In 1977, there were no continental European transfer stations preparing shredded RDF for 100 percent RDF firing or co-firing, i.e. only mass burning is practiced.

Composition of Refuse

Physical Composition of Refuse

Refuse composition varies from place to place and from time to time. Some typical refuse compositions are presented in Table A-6.

Moisture Content

In one analysis, the moisture percent ranged from a low average of 22.5 percent to a high average of 32.5 percent. The average among six (6) facilities was 27.1 percent.

Heating Value of Refuse

Definitions and Calculations

Heating values are expressed in either of two manners: (1) Lower Heating Value (LHV), and (2) Higher Heating Value (HHV). This has occasionally lead to confusion even though the difference is only about 7 to 15 percent. The Europeans have the practice of using Lower Heating Value (LHV) versus the U.S. practice of using Higher Heating Value (HHV). The difference arises from the heat of condensation of the hydrogen-produced

TABLE A-6. COMPOSITION OF MUNICIPAL SOLID WASTE IN SWITZERLAND, USA, AND BRITAIN

Constituants	Composition by Weight Percent (%) (Location and Source) Switzerland			U.S.A.		Britain	
Source:	1	2	3	1	4	5	6
Food waste	20	12	14.5	6	14	26	13
Textiles	4	2.5	3.0	3	-	2	2.5
Paper	36	30	33.5	40	55	37	51.5
Plastics	4	7	2	4	1	1.5	1.0
Leather and rubber	2	-	-	2	-	-	-
Wood	4	6	2.5	2	4	-	-
Glass	8	5	8.5	17	9	8	6.5
Ferrous and nonferrous metals	6	7	5	9	9	8.5	6.5
Street sweepings and garden waste	6	-	-	5	5	2	3
Stones, dust, and other debris	10	33.5	31	12	3	15	16

Sources:
1. National averages as published by EAWAG (1971) (used for planning Hagenholz)
2. Municipal solid waste of Geneva (1972)
3. Municipal solid waste of Zurich (1963/1964)
4. Unknown
5. London (1972)
6. Birmingham (1972)

water in the flue gas.

General Comments on Refuse Heating Values

Figure A-1 shows how the lower heating values have risen over the years in various European Cities. Generally speaking, most of the visited plants have current values between those of Duesseldorf on the low side and Stockholm on the high side.

Table A-7 presents LHV's as reported for most of the 15 visited plants. In several instances the actual LHV has been higher than that used in the plant design. Energy values for refuse components are shown in Table A-8.

In some cases the difference between the design and actual values can be traced to the amount and type of industrial waste now being sent to the system as opposed to that originally anticipated.

Recently the lower heating value averages have ranged from 1600 to 2800 Kcal/Kg (2,850 to 5,000 Btu/pound). Simply adding 11 percent will result in rough estimates of higher heating values of 1,776 to 3,108 Kcal/Kg (3,197 to 5,594 Btu/pound). Thus today, European refuse contains almost as much energy as does American waste.

During the past 25 years, there has been a dramatic increase in the refuse heating values in virtually all European communities. This was caused by three factors. First, Households formerly disposing large volumes of inert furnace ash no lonnger do so because so many furnaces were converted to oil or gas. Also, newly built homes normally have oil or gas furnaces. Second, the dry and combustible wastes that formerly were burned at home in furnaces and stoves are now discarded for the trashman. Third, many housewives that formerly walked to the store around the corner with a knit sack to carry unpackaged groceries, now drive to the store where packaged (paper and plastic) groceries are loaded into paper sacks. Similarly other consumer goods are now packaged.

Refuse Generation and Burning Rates Per Person

Refuse generation rates are not always equivalent to refuse burning rates. There occasionally is the tendency to confuse these rates for several reasons. Sometimes people will report a generation rate that includes construction waste, demolition debris, power plant ash, sewage sludge, waste oils and solvents, pathological waste, etc. The above items are normally not permitted into the refuse pit and are hence excluded from any calculation of the per capita refuse burning rate. Household bulky waste is sometimes accepted into the pit depending on the particular system.

Readers of this report are presumably interested primarily in "solid combustible waste loads" that are "combusted to produce energy". Thus Table A-9 was constructed to show reported tonnages of only combustible loads of refuse (household, commercial and light industrial) that are combusted at the visited refuse fired energy facilities. The figures have been divided by the generation population as accurately as is possible.

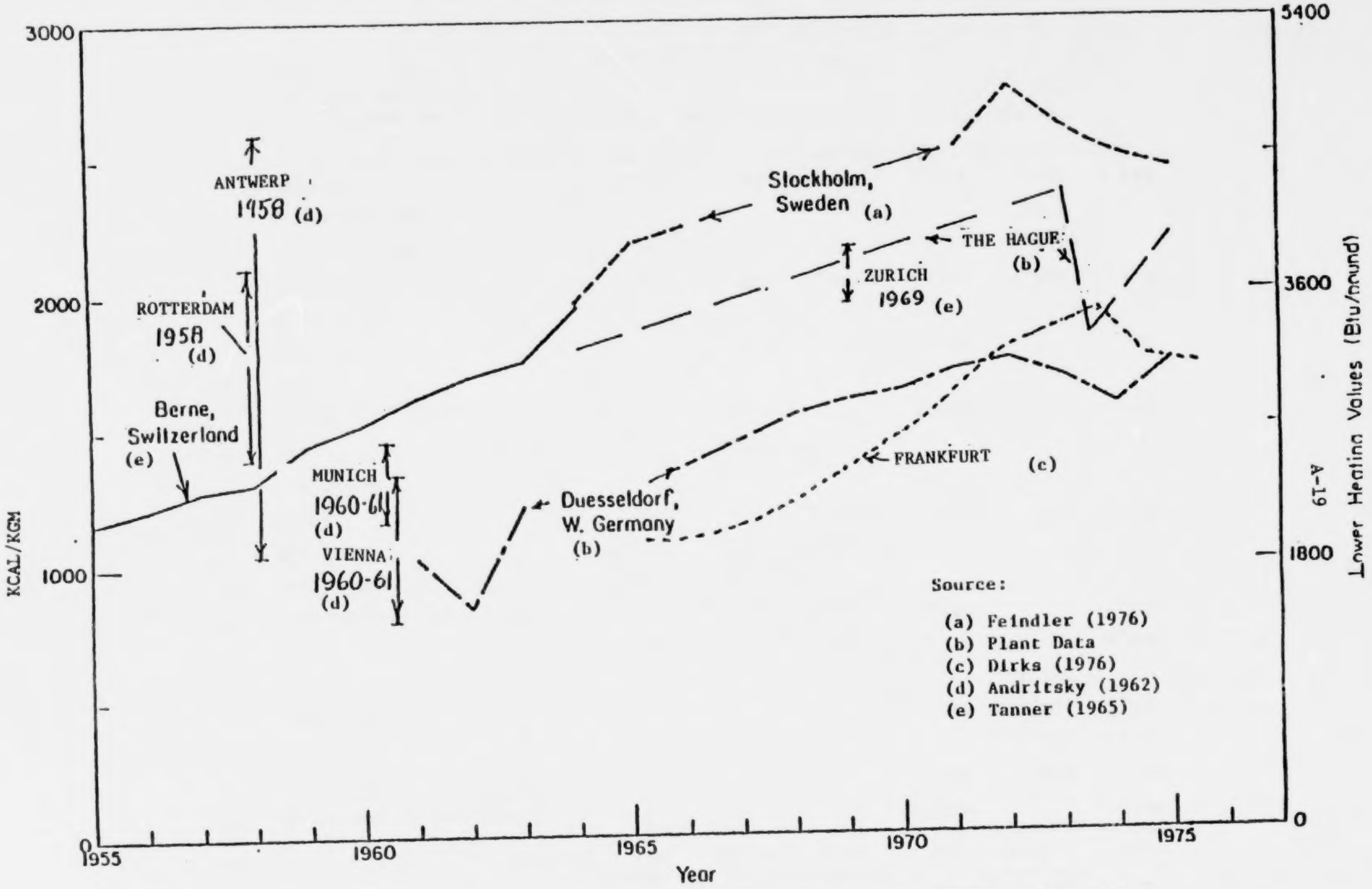


FIGURE A-1. ANNUAL AVERAGE LOWER HEATING VALUES FOR BERNE, STOCKHOLM, FRANKFURT, THE HAGUE AND DUESSELDORF AND RANGE OF VALUES FOR OTHER CITIES (See References at end of chapter S - Furnace Wall)

TABLE A-7. REFUSE LOWER HEATING VALUES: ASSUMPTION FOR PLANT DESIGN AND ACTUAL

Trip		Refuse Lower Heating Value (kcal/kg) Assumed LHV for Plant Design Low	Medium	High	Actual LHV Low	Medium	High
1	Werdenberg-Liechtenstein				2,800		3,360
2	Baden-Brugg				1,700	1,800	1,900
3	Duesseldorf					1,700	1,800
4	Wuppertal				900	2,250	2,600
5	Krefeld					1,750	
6	Paris:Issy	900		2,500	1,700		1,900
7	Hamburg:Stellinger-Moor	1,800	1,900	2,200	1,800		2,500
8	Zurich:Hagenholz						
	No. 1-3	1,000		1,800			
	No. 4	1,600		3,300	2,200		2,400
9	The Hague						
	No. 1-3		2,066				
	No. 4		2,500		1,800	2,100	2,300
10	Dieppe						
11	Goteborg				2,300		2,400
12	Uppsala						
13	Horsens	1,800	2,000	2,200	2,500	2,800	3,140
14	Copenhagen:Amager	1,000		2,500		2,200	
15	Copenhagen:West					2,200	
	AVERAGE	1,420	2,117	2,540	1,967	2,100	2,430

(a) The large open spaces in various report tables indicate that information was not readily available.

(b) "Roughly" o HHV = 1.11 LHV*
- o HV (Btu/pound) = 1.8 HV (kcal/kg)
- o HV (Btu/pound) = 1.11(1.8) LHV (dcal/kg) = 2.0 LHV (kcal/kg)

* The HHV will range from 7% to 15% more than the LHV depending on hydrogen content.

TABLE A-8. ENERGY VALUES OF SELECTED REFUSE COMPONENTS (DRY)

	kcal/kg
Average waste	1600 - 3400
Constituents (in relation to the dried products)	
paper	4160 - 4460
plastic, leather, rubber	5600 - 6450
food waste	4775
textiles	4500
wood	4820
Forest and wood industry residues	4090
Agriculture and food industry waste	2780
Tires	8230
Bituminous coal	5600 - 8100
Gasoline	11400
Methanol	5420

Source: Various sources.

TABLE A-9. EUROPEAN AVERAGE REFUSE GENERATION AND BURNING RATES PER PERSON (1976-1977 PERIOD)

	Household and Light Commercial	Other Commercial and Light Industrial	Total Combustible Loads[b]
		kg/person/year	
Low	275	25	300
Average	318	45	363
High	350	100	450
		pounds/person/year	
Low	605	55	660
Average	700	100	800
High	770	220	990
		kg/person/day	
Low	0.75	0.07	0.82
Average	0.81	0.12	1.00
High	0.96	0.27	1.23
		pounds/person/day[a]	
Low	1.66	0.15	1.80
Average	1.92	0.27	2.20
High	2.11	0.60	2.71

(a) Calculated at 365 days/year even though some systems operate only 5, 5-1/2, or 6 days per week.

(b) Full weight of contents in a vehicle where contents are destined for combustion.

Source: Battelle estimates.

We believe that the best estimate for combustible household refuse plus light commercial waste is 318 kg per person per year (700 lb/pers/yr). The range from this estimate varies by country, by population density, and by availability of alternative disposal means.

However, the range of volume for burning other commercial and light industrial waste is more dramatic. The amount of light industrial waste varies extensively depending on: (1) local industrial composition, (2) whether the facility has a shear, (3) opening of the feed chute, and (4) policy of the operator. In this waste category, the rate can vary from 25 to 100 kg per person per year. It is really more meaningful to emphasize the range than to concentrate on an average. But if one assumes a 45 kg per person per year average, the total household, commercial and light industrial waste generation rate becomes:

- 363 kg per person per year (or)
- 800 pounds per person per year (or)
- 1.00 kg per person per day (or)
- 2.2 pounds per person per day.

Total Operating System

Many plants provided a great amount of data in large comprehensive tables. Such data provide the opportunity to analyze the plant as a total operating system. Interrelationships and ratios can have more meaning if the data can be viewed together. Data are included on thermal and combustion efficiency, volume reduction, shut-downs, operating time, amount of waste received, cooling water, steaming rate, steam production, air pressure, availability, etc. Data are presented without extensive analysis.

Energy Utilization

Because the typical European resource recovery plant has such a complicated energy use pattern, it was necessary to categorize information into first, second and third step energy forms and uses as shown in Table A-10.

In the first step, the energy in flue gas can be used directly to dry sewage sludge or produce hot water or steam in a boiler. There is a geographic split with steam being produced in central and southern Europe, while hot water is often produced in Scandinavia. Central Europeans claim that steam is more useful while the Scandinavians make calculations to show that hot water is more efficient.

We have wondered whether the geographic difference is an accident of corporation location. The four steam related water-tube wall vendors (Von Roll, Widmer & Ernst, Martin and VKW) happen to be located in Central Europe. Both Volund and Bruun and Sorensen, the continent's leading refractory wall furnace, hot water generator vendors are in Denmark. The water-tube wall furnace/boilers can economically produce high temperature steam. Producing hot water in such a water tube wall furnace might be considered a waste of capital investment money. The refractory wall furnaces are generally less expensive and would have technical difficulties raising steam temperature to much above 333C (632F).

So the question arises, "Do the Danes purchase refuse fired hot water systems (1) because Volund and Bruun and Sorensen are there

TABLE A-10. THREE STEPS OF ENERGY FORM AND USE AT VISITED EUROPEAN PLANTS

	Werdenberg-Liechtenstein	Baden-Brugg	Duesseldorf	Wuppertal	Krefeld	Paris: Issy	Hamburg: Stellinger-Moor	Zurich: Hagenholz	The Hague	Dieppe (And Deaville)	Gothenburg	Uppsala	Horsens	Copenhagen: Amager	Copenhagen: West	TOTAL
First Step	Energy Form And Use															
Flue Gas to Dry Sewage Sludge					x								x			2
Flue Gas to Heat Hot Water in Boiler													x	x	x	3
Flue Gas to Heat Steam in Boiler	x	x	x	x	x	x	x	x	x	x	x	x				12
Intake of Exhaust Air from Other Process for Distruction					x			x			x	x[2]	x			5
Second Step	Energy Form And Use															
Hot Water for Specific Industrial Uses																0
Hot Water for Internal Uses													x	x	x	3
Hot Water to the Wastewater Treatment Plant		x														1
Hot Water for District Heating (Direct)													x	x	x	3
Steam for District Heating (Direct)						x		x								2
Steam for Specify Industrial Uses	x				x			x				x				4
Steam for Internal Uses	x	x	x	x	x	x	x	x	x		x	x				11
Steam to Make Hot Water	x		x					x			x	x				5
Steam to Make Electricity	x	x	x	x	x	x		x	x							8
Steam Dry Sewage Sludge										x						1
Third Step	Energy Form And Use															
Hot Water for District Heating (Indirectly From Steam)	x		x					x			x	x				5
Electricity for Specific Industrial Uses		x														1
Electricity for Internal Uses	x			x	x			x								4
Electricity for the Network	x	x	x	x		x	x	x	x							8
Electricity for the Wastewater Treatment Plant		x			x											2
Large Quantities of Steam Wasted in Condensors	x			x			x				x					4

1. Only if extra electricity remains after Internal Uses.
2. Exhaust gases from the separate pathological waste incinerator and the dextrose waste industrial waste incinerator are both blown into the refuse fired steam generator.

locally and that is what they sell or because hot water systems are more efficient and relevant to northern climates? These researchers do not have a clear answer at this time.

As a summary Table A-11 was prepared showing how often key functions are included in the design.

Many of the foregoing comments refer to salable energy uses. Internal uses and losses also need to be considered by the designer. There are some necessary internal uses while there are some internal losses that need to be minimized as shown in Table A-12.

TABLE A-11. KEY ENERGY FUNCTIONS OF 15 VISITED SYSTEMS

	Number of Systems Having the Energy Use Category	Percent
• Sludge Destruction	3	20
• District Heating	9	60
• Electricity Export to the Network	8	53
• Industrial Process Steam	5	33
• Destruction of Exhaust Gases From Other Processes	5	33
• Systems Wasting Large Quantities of Steam on Roof	4	27
• Internal Use of Energy Produced	14	93

(out of a sample of 15 plants)

District Heating

District heating (D.H.) commercialization varies extensively by country as was shown in Figure A-2. The world's largest D.H. country is the U.S.S.R. Commericalization is faster with more centralized planning and control where there is less pressure on immediate economic returns. In Western Europe, West German systems deliver the most energy. Scandinavia, however, has the highest per capita rate.

The American D.H. systems are mostly steam. In recent years many European D.H. systems use only hot water. Several Europeans met on the tour suggested that the lackluster D.H. situation in America of the last 20 years was partially the fault of using steam and not hot water. "Energy losses are greater with steam, maintenance is higher and steam can only be transported 1/3 the distance as hot water" would be a typical European assessment.

These researchers are not sure if the above is the complete story. For sure, as the U.S. EPA and State agencies improve the atmospheric environment, there has been pressure on D.H. systems to spend large sums for pollution control equipment or to close. Many have chosen to close. Often systems spend money on emissions cleanup but let the steam lines fall into disrepair.

TABLE A-12. INTERNAL USES AND LOSSES OF REFUSE DERIVED ENERGY

Uses

- Preheat incoming combustion air
- Reheat outgoing combustion air after scrubbing
- Preheat boiler feedwater
- Heat the plant interior space
- Electrify many parts of the plant
- Dry sewage sludge internally before combustion
- Blow steam through sootblower

Losses

- Cool steam in condensers
- Escapes in stack
- Escapes in pressure relief valve
- Escape in ash and quench water
- Escape in sampling for air quality

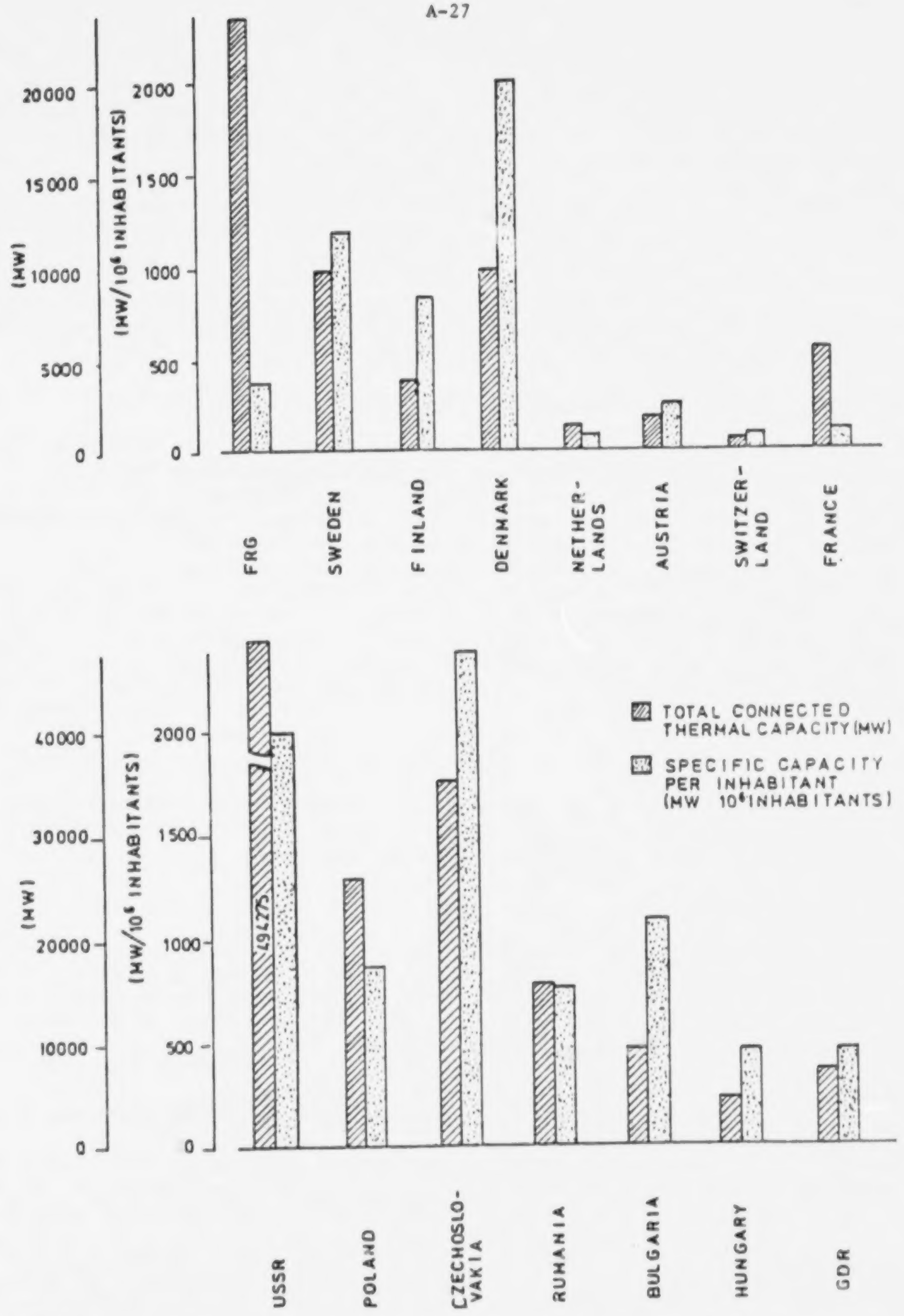


FIGURE A-2. CONNECTED AND SPECIFIC CAPACITIES IN EUROPE (Courtesy of Lennert Lindenberg AB Energi Konsult at the Swedish District Heating ing Workshop obtained from Scholten, Timm. Survey of Existing District Heating Systems. Nuclear Technology. Vol. 38)

It is the opinion of these researchers that the issues raised in the above two paragraphs have unnecessarily soured decision makers attitudes in America to the detriment of full consideration of Refuse-Fired District Heating Systems.

District Heating, however, is not necessarily desirable for all applications as is shown in Table A-13. It is normally "very favorable" for downtown, high rise buildings. Even though the table states that it is "not possible" to provide D.H. for one-family houses, it occasionally is provided in Sweden and Denmark.

Table A-14 presents several favorable demand aspects of district heating steam and chilled water systems as prepared for the American situation.

District Cooling (Not Observed in Europe)

Six years ago Battelle performed a study of the potential for refuse fired district heating and cooling systems across the U.S.A. The study concluded that there were definite economic benefits to the system if district cooling could be provided in the summer. The Nashville Thermal Transfer Corporation in Nashville, Tennessee, was the model.

Technically, the economic objectives can be accomplished in either of two ways. In Nashville steam is sent to an adjoining Carrier centrifugal chiller station equipped with large turbines, compressors and condensers. Cold water at 5 C (41 F) is then pumped to over 30 downtown office buildings. The other method that will be used by the Harrisburg Incinerator Authority in Pennsylvania is to keep sending hot steam through the lines in the summer. Building owners who desire air cooling can direct steam to their own adsorption chilling stations--one in each basement.

Without question, in the total subject area of refuse to energy, the technology flow needs to be from Europe to the U.S.A. However, those Europeans who desire to increase summer loads and overall financial results might do well to look at district heating and cooling as practiced in Nashville, Tennessee, and Harrisburg, Pennsylvania.

Underground Distribution

Every district heating system viewed had unique underground pipe distribution schemes. In all hot water systems, there is a return warm water pipe. However, in steam systems, the designers have a choice of returning condensate or not. Many designers wish to conserve water and will try to minimize corrosion in their condensate return pipes. Others with a healthy fear of the corrosive effects will specify a once through recycle system.

All hot water and some steam systems viewed had packed tunnels, i.e. packed with dirt, gravel, insulation, etc. See Figures A-3, 4, 5, and 6. Several steam systems, however, used human walk-through tunnels such as detailed later at Zurich. Duesseldorf, because of the railroad and other underground utilities, uses an exposed overhead pipe also as shown later.

Relation of Refuse as a Fuel in the Long Term Community Plan for Community Electrical Power, District Heating and Cooling

TABLE A-13. ATTRACTIVENESS OF DISTRICT HEATING AS A FUNCTION OF DENSITY OF ENERGY USE[(a)]

Peak Density MM Btu/hr-acre	Average Corrected Load Density MM Btu's/yr-acre	Type of Land Use (Typical)	Attractiveness (Relative)
0.97	<2470	Downtown, High-rise	Very favorable
0.70-0.97	1782 to 2470	Downtown, milti-story	Favorable
0.28-0.70	713 to 1780	City Core, Commercial or multi-family houses	Possible
0.17-0.28	433 to 713	Residential, four two-family houses	Questionable
0.17	<433	One family houses	Not possible

(a) This reference presents heat in units of millions of Btu's per hour-acre/at peak load. This interpretation of the data was confirmed with Dr. Michael A. Karnitz of ORNL in a telephone conversation November 3, 1978.

Average load may be approximated by:

$$\frac{\text{MM Btu peak/hr-acre (24 hr/day) (6366 heating degree days/yr)}}{\text{(60 heating degree days/day at peak)}}$$

or

$$\frac{\text{2546.4 MM Btu/year average}}{\text{MM Btu/hr peak}}$$

Thus, the data in the reference were converted from MM Btu (hr-acre/peak) to MM Btu/yr-acre (average) by multiplying by 2546.4.

Source: Wahlman, Erik, "Energy Conservation Through District Heating - A step by Step Approach", Swedish District Heating Workshop, October 1978, p.7.

TABLE A-14. FAVORABLE DEMAND ASPECTS OF DISTRICT HEATING AND COOLING SYSTEMS IN THE U.S.A.

1. Large, dense load area
2. Land available for system
3. Sufficient initial customers to assure adequate load
4. Urban renewal slated or under way
5. Location in state capital
6. Local coal-burning steam utility desiring to leave business because of pollution regulations
7. Local district heating utility desiring to increase business with addition of chilled water
8. Increasing conventional fuel prices
9. Uncertain conventional fuel availability
10. Lack of interest in solid waste for electrical generation or industrial steam
11. Flexible rate setting for district heating and cooling products

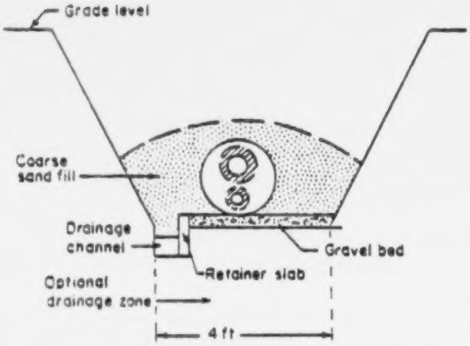

Grade level
Coarse sand fill
Drainage channel
Gravel bed
Retainer slab
Optional drainage zone
4 ft

FIGURE A-3. STEAM DISTRIBUTION AND RETURN CONDENSATE PIPES AT WERDENBERG

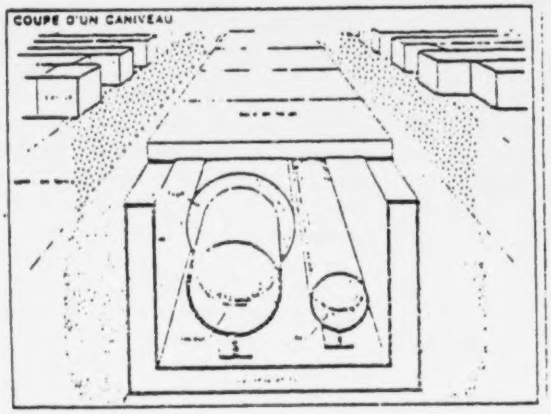

COUPE D'UN CANIVEAU

FIGURE A-4. STEAM DISTRIBUTION AND RETURN CONDENSATE PIPES AT PARIS

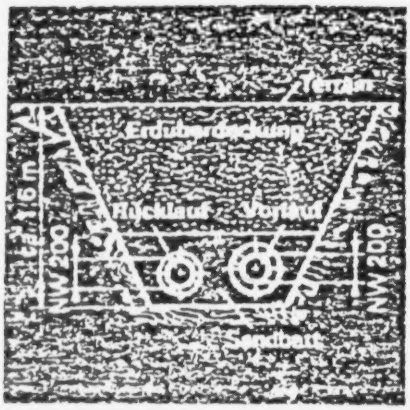

Terrain
Erdüberdeckung
Rücklauf
Vorlauf
ca. 1.6 m
NW 200
NW 200
Sandbett

FIGURE A-5. HOT WATER PIPES AT WERDENBERG

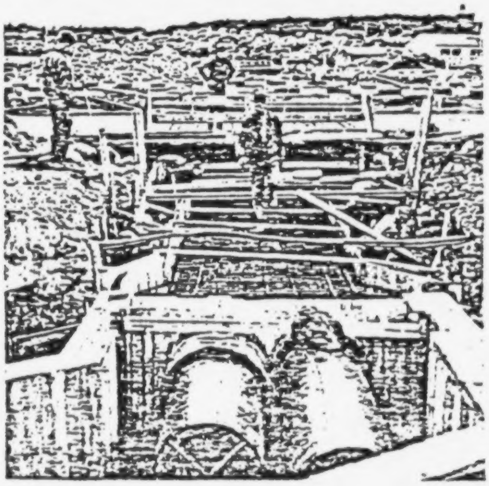


FIGURE A-6. HOT WATER PIPES AT UPPSALA

The following several pages demonstrate how refuse fuel could fit into a community's total long term energy program.

One of the basic features of community district heating development is that it progresses in stages. Five key stages are shown in Figure A-7 and are as follows:

Stage 1: Consumer system
Stage 2: Portable oil or gas fired central substations
Stage 3: Permanent district heating stations
Stage 4: Cogeneration of electricity and district heat from refuse
Stage 5: Base load with distant nuclear waste heat.

Almost any existing consumer heating system energy plan can be retrofitted for hot water district heating.

Often portable oil fired district (or central) heating substations are erected for subdivisions. When two to five of these are in an area it becomes economical to erect a permanent district heating station.

Permanent operations as district heating stations can be used in two ways to enhance refuse operations as portrayed in Figure A-8. First, when the RFEP is providing the base heating load, the permanent boilers can be used for peaking. Second, when there is either not enough refuse input or energy demand output,then the boilers can be used instead of firing the expensive to operate base load refuse fired energy plant.

Repeatedly on the European tour mention was made of the advantages of cogeneration. A simple power station with a condensing turbine must waste much energy in a condenser. However with an energy efficient cogeneration plant that has a back pressure turbine to provide electricity and then steam for district heating, energy efficiency can be more than doubled.

The Swedes are considering three situations where they would use waste heat from nuclear power stations. (See Figure A-9.)

In summarizing the five stages, it is important that each stage be developed before future stages are implemented. Any particular stage may require 6 to 12 years before the savings in fuel cost equals the extra expense of installing that stage. Another, perhaps humbling point for resource recovery, is that in the long term, refuse-to-energy systems will be a limited factor in the total energy picture simply because there is not enough energy in waste and enough volume of waste. Once again the point is made that energy recovery enables refuse disposal in an economical manner. But it is not the panacea for the world's energy problems.

Energy Marketing and Standby Capacity

Customarily, established energy customers having their own boilers will accept interruptible steam---but at a reduced price. Commonly there are situations where (because of the investments that potential customers have in existing boilers) such customers will use marginal costing instead of total costing. Two examples are shown:

Example (1). A new refuse-fired energy plant is being considered that would require \$3.25 per 1000 pounds steam as a revenue from large, steady industrial customers. A new factory might locate in an adjoining new industrial park. A new oil-fired

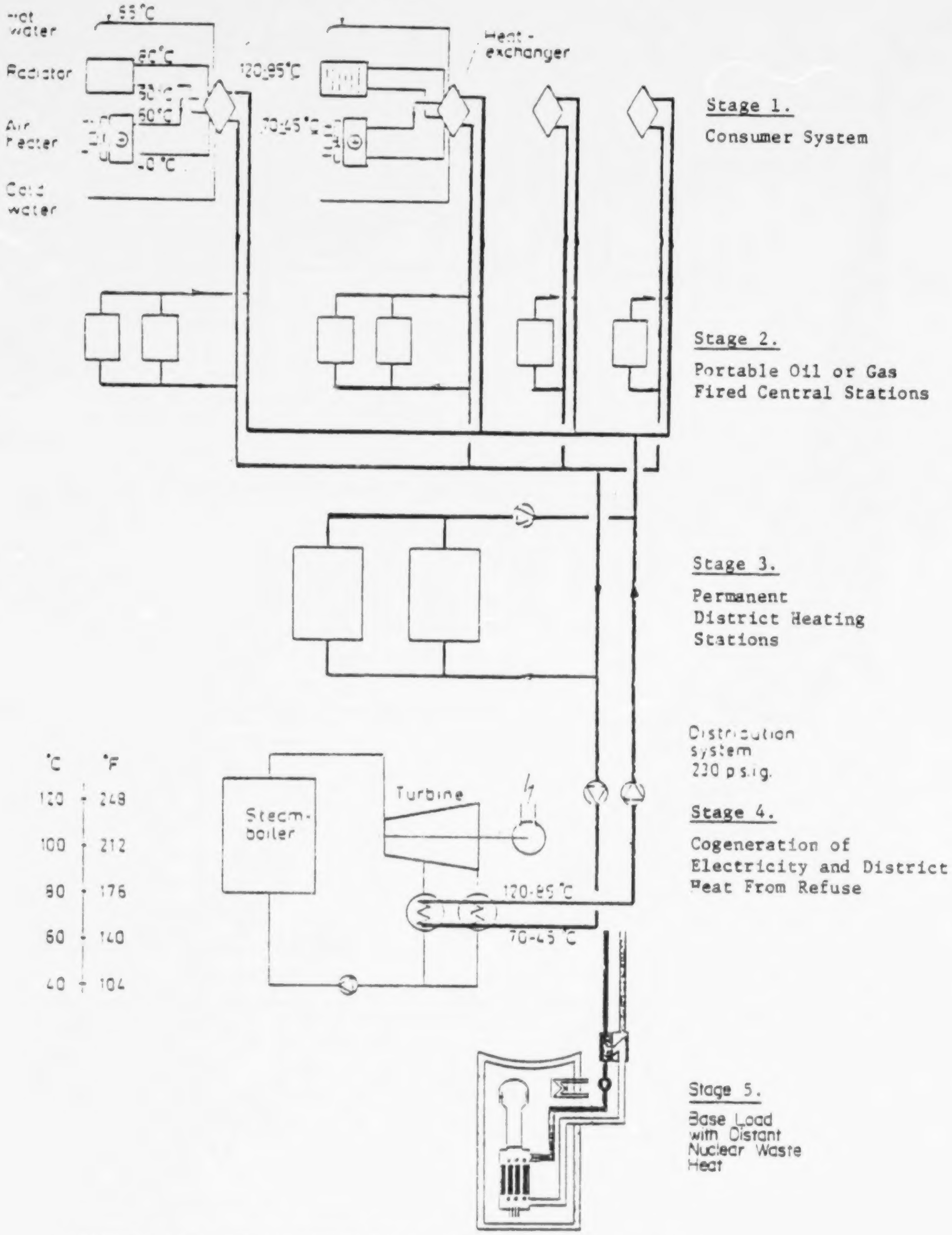

Hot water
55°C
Radiator
80°C
50°C
60°C
Air heater
40°C
Cold water
120-85°C
70-45°C
Heat-exchanger
Stage 1.
Consumer System
Stage 2.
Portable Oil or Gas Fired Central Stations
Stage 3.
Permanent District Heating Stations
Distribution system 230 p.s.i.g.
Stage 4.
Cogeneration of Electricity and District Heat From Refuse
°C
°F
120
248
100
212
80
176
60
140
40
104
Steam-boiler
Turbine
120-85°C
70-45°C
Stage 5.
Base Load with Distant Nuclear Waste Heat

FIGURE A-7. TOTAL ENERGY PLAN BUILT UP IN FIVE STAGES

(Courtesy of Erik Wahlman, Theorell & Martin Energi Konsulter AB at the Swedish District Heating Workshop)

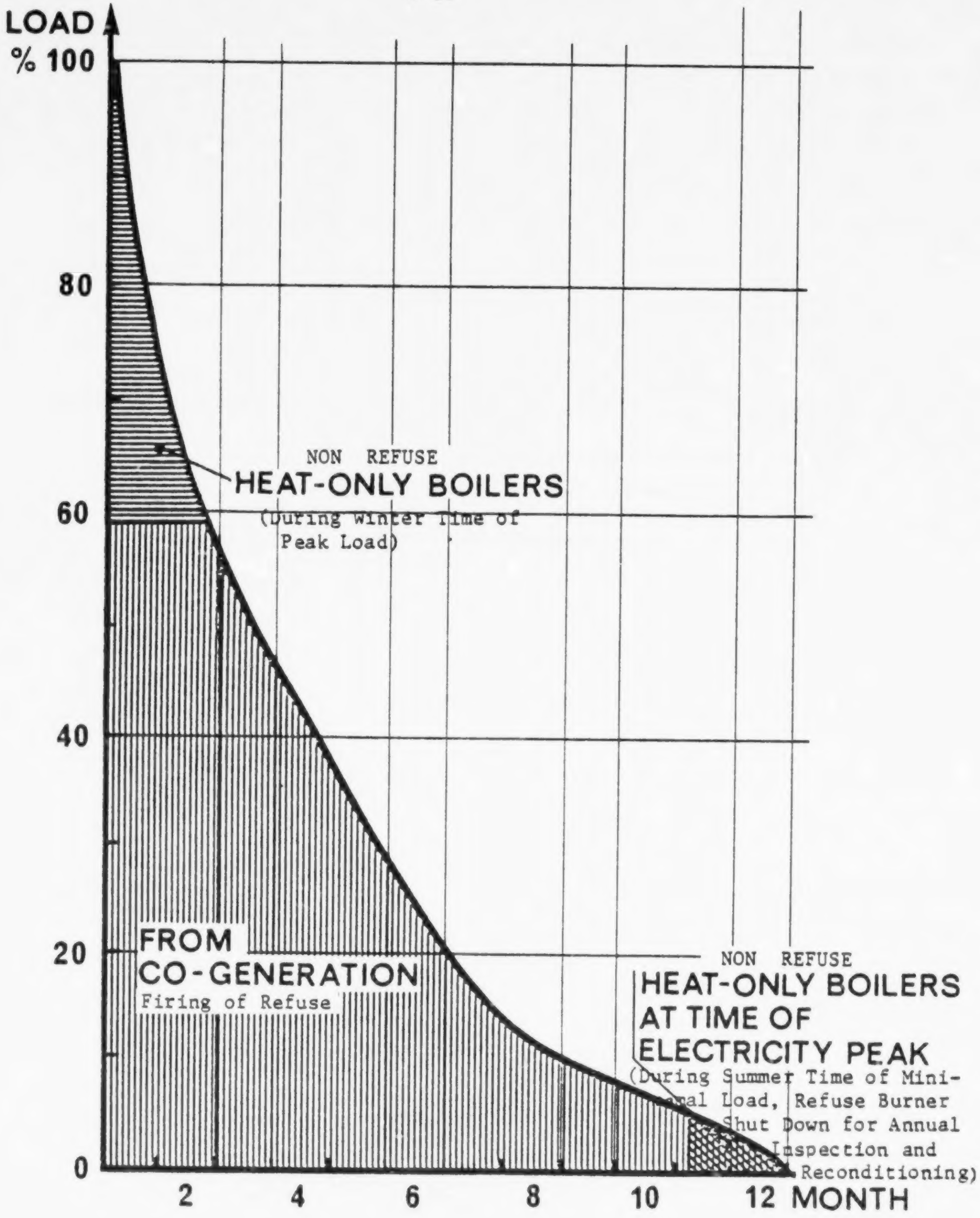


FIGURE A-8. HEAT LOAD DURATION CURVE AND LOAD-SPLIT. HEAT ONLY PACKAGE BOILERS USED (1) FOR PEAKING, (2) WHEN THERE IS NOT ENOUGH REFUSE SUPPLY OR (3) WHEN ENERGY DEMAND IS TOO LOW or (4) DURING SHUTDOWN FOR INSPECTION AND RECONDITIONING (Modification of Studsvik Energiteknik AB figure given at the Swedish District Heating Workshop)

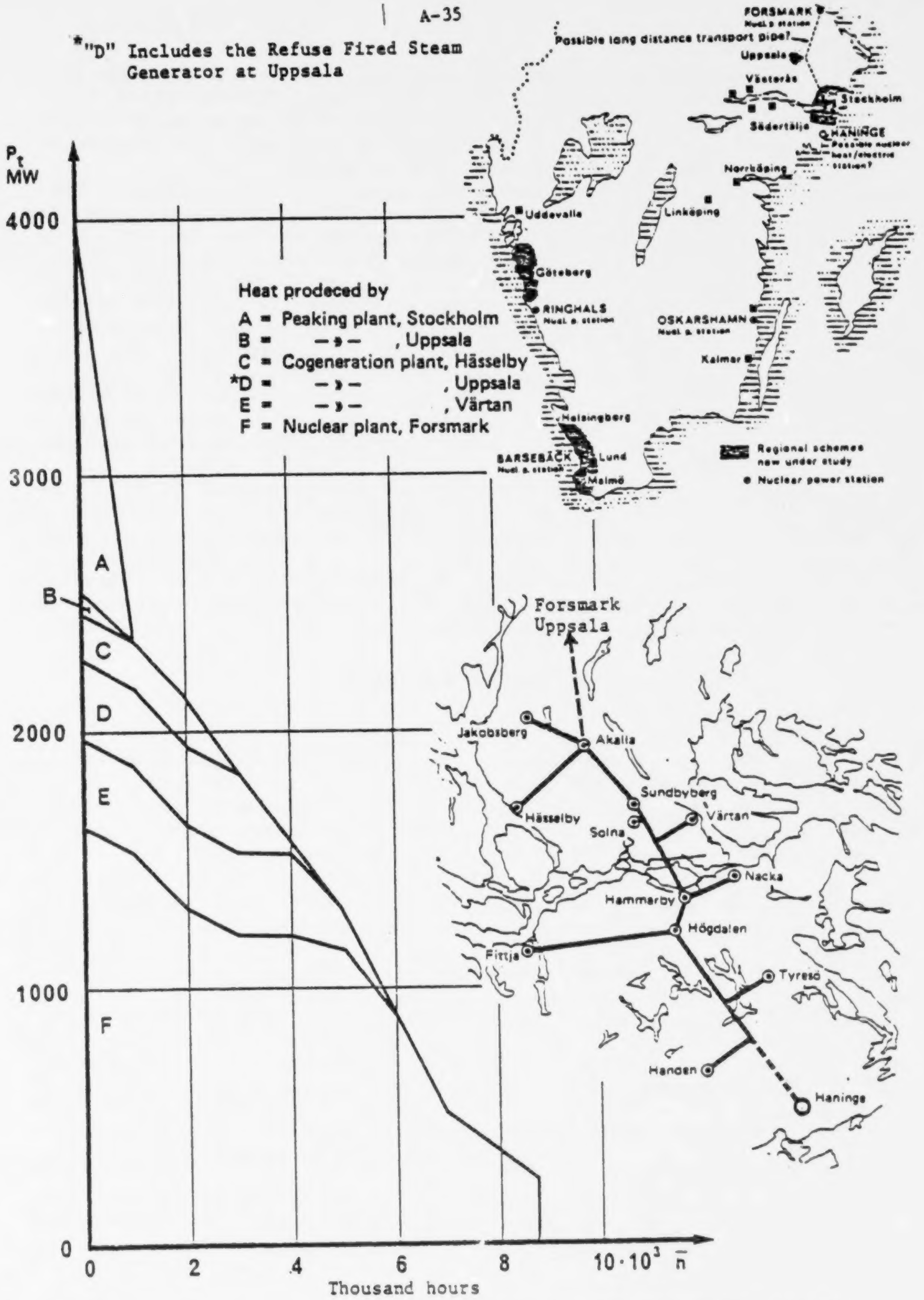

*"D" Includes the Refuse Fired Steam Generator at Uppsala

Figure A-9. HEAT PRODUCED BY EACH UNIT FOR THE OPTIMUM CASE IN THE LONG RANGE PLAN FOR DISTRICT HEATING SUPPLY IN THE STOCKHOLM AREA USING OIL, REFUSE AND NUCLEAR POWER industrial boiler could be constructed to produce steam at a cost of $4.50 per 1000 pounds steam. The new plant could need the guarantee of continuously supplied steam in case of a garbage strike or malfunction of equipment. At this price it is likely a contract could be signed.

Example (2). The same refuse-fired energy plant is being considered that would again require $3.25 per 1000 pounds as revenue. An existing factory has been approached that has existing coal-fired boilers reliably producing steam for $2.50 per 1000 pounds. ($2.00 for fuel and $0.50 for operations and maintenance). The factory would keep its coal-fired unit as an emergency backup. In addition, they already have a small 50,000 pound per hour package oil-fired boiler. The plant manager's accountants tell him to ignor the "sunk costs" in his boiler such as the boiler's original cost or the remaining principal or interest payments. Often in such a situation the plant owner refuses to sign the steam purchase contract.

Hence, we conclude, if the potential energy customer is to provide his own supplemental firing from the existing boilers (and not from the refuse energy plant), then the customer will use marginal costing rather than total costing. He will ignore sunk costs and will require a lower price for externally supplied steam. Occasionally, the factory's marginal cost to raise its own steam will be less than the total cost to be covered of a new refuse-fired energy plant. (RFEP)

Economics and Finance

Captial Investment Costs

Capital investment costs are displayed in Table A-15a and A-15b for the 15 plants visited. The data presented are those provided by local officials. The definition of the numbers are not necessarily consistent. The reader will have to review the specific comments as shown in the trip reports to sort out the data depending on the type of numbers desired.

Land, for example, is sometimes included if overtly paid for. However, if the refuse fired energy plant was built on the grounds of an existing municipally owned Energy and Environmental Park, the land might be considered free.

Some operators have "within-the-gate" accounting schemes that have combined and inseparable investment data. For example: consider the newly constructed RFEP, administration building, truck repair building and bicycle hall that were funded out of one financing instrument.

American vendors of European licenses were quick to discourage placing too much emphasis on the following investment figures. What they hope to market in America in the 1980's bears little resemblance to what was built in the late 1960's or early 1970's as described in this report.

To quote from from the 1976 "Solid Waste Management Guidelines" as published by the U.S. EPA:

> "It is EPA's firm belief that attempts to predict (and compare) costs of various types of plants in a general way, apart from local circumstances, is more likely to mislead than inform. The

Table A-15a. SUMMARY OF CAPITAL INVESTMENT

	Total Facility Energy and Envir. Biggest Cost	Total Facility Part Refuse to Energy Plant by Staff	Chute to Stack Costs Only Mech. & Elec.	Finance Year	Refuse Fired Steam Generator Total Copital Investment Best Estimate for Comparative Purposes
Werdenberg	18,000,000 S. Fr.	13,000,000 SF			13,000,000 SF
Baden-Brugg		16,400,000 SF		1970	16,400,000 SF
Duesseldorf Units #1-4		34,500,000 DM	15,500,000 DM	1965	46,300,000 DM
Units #5			11,800,000 DM	1972	
Wuppertal	126,000,000 DM	126,000,000 DM	54,400,000 DM	1975	126,000,000 DM
Krefeld		60,000,000 DM		1976	60,000,000 DM
Paris:Issy		110,000,000 F. Fr.		1962	110,000,000 F.Fr.
Hamburg:Stellinger-Moor		48,000,000 DM	25,000,000 DM		48,000,000 DM
Zurich:Hagenholz Units #1-2	56,000,000 S. Fr.	45,694,000 S. Fr.	23,000,000 S. Fr.	1969	59,694,000 S.Fr.
Units #3		14,000,000 S. Fr.	11,430,000 S. Fr.	1973	
The Hague #1-3		45,000,000 Gl.		1967-68	62,000,000 Gl.
#4		17,000,000 Gl.		1973-74	
Dieppe	13,663,000 F. Fr.	7,933,000 F. Fr. 750,000 F. Fr.	6,400,000 F. Fr.	1969 1971	8,683,000 F.Fr.
Gothenburg	120,000,000 S. K.	98,000,000 S. Kr.		1971	98,000,000 S.Kr.
Upsala Fur. 1, 2 Boiler 1		3,400,000 S. Kr.		1960	11,050,000 S.Kr.
Fur. 3, Boiler 2			1,000,000 S. Kr.	1965	
Fur. 4, Boiler 3			4,000,000 S. Kr.	1970	
Crane, ESP, Shear, etc.				1971	
To replace entire Uppsala systems in 1977 dollars	60,000,000 S. K.				
Horsens (with spray cooling tower)		11,094,423 D. Kr.	6,514,873 D. Kr.	1973-74	18,203,000 D.Kr.
Boiler & Pipe		7,108,544 D. Kr.		1976-77	
Copenhagen:Amager		117,600,000 D. Kr.	45,000,000 K. Kr.	1970-72	157,600,000 D.Kr.
Improvements		40,000,000 D. Kr.		1973-77	
Copenhagen:West Units #1-3		140,580,022 D. Kr.		1969-70	204,973,000 D.Kr.
Units #4 etc.		64,392,612 D. Kr.		1975-76	

Table A-15b. SUMMARY OF CAPITAL INVESTMENT (Continued)

	Weighted Average Year of Investment used to Select Exchange Rate	Exchange Rate U.S.$	U.S. Dollars in Weighted Ave. Year	Actual 1976 Tonnes Per Year	Tons Per Year	Tons per Day at 365 Days/Yr.	Capital Cost Per Daily Ton Capacity
Werdenberg	1973	3.244	4,007,000	26,018	28,620	78	51,103
Baden-Brugg	1970	4.316	3,800,000	41,693	45,862	126	30,243
Duesseldorf	1967	3.999	11,578,000	297,359	327,095	896	12,920
Wuppertal	1975	2,622	48,055,000	178,000	195,800	536	89,382
Krefeld	1976	2.363	25,391,000	114,000	125,400	344	73,905
Paris	1962	4.900	22,449,000	588,904	647,794	1,775	12,649
Hamburg:Stellinger-Moor	1971	2.622	18,307,000	420,680	462,748	1,268	14,440
Zurich:Hagenholz	1970	4.316	13,831,000	223,595	245,955	674	20,525
The Hague	1970	3.598	17,237,000	229,000	251,900	690	24,976
Dieppe	1969	5.558	1,562,000	14,892	16,381	45	34,804
Gothenburg	1971	4.858	20,173,000	242,536	266,790	731	27,599
Upsala	1967	5.165	2,139,000	52,040	57,244	157	13,639
Horsens	1975	6.178	2,946,000	18,909	20,800	57	51,697
Copenhagen:Amager	1971	6.290	25,056,000	255,000	280,500	768	32,604
Copenhagen:West	1971	6.843	29,954,000	234,230	257,653	706	42,434
TOTAL AVERAGE-1971			246,485,000 16,432	2,936,856 195,790	3,230,542 215,369	8,851 590	35,541

range of assumptions regarding specific design, reliability, markets and other factors is too great to make such an analysis meaningful."

Initial Capital Investment Cost per Daily Ton

Initial capital investment cost per daily ton capacity has risen dramatically from 1960 the present. Earlier values of $13,000 per daily ton compare with 1975-76 values of $50,000 to $90,000 per ton. More recently there have been some American proposals near $100,000 per daily ton capacity. These numbers are displayed in Figure A-10. There are seven general reasons for this dramatic price growth:

- Inflation
    - Land
    - Capital equipment purchases
    - Construction service fees
    - Construction labor and materials cost
- Interest rates during construction
- Exchange rate devaluation
- Corrosion protective equipment designs
- Architecture and landscaping for neighborhood acceptance
- More complex energy use systems
- More air pollution control equipment

Inflation. Generally speaking, with the exception of West Germany, costs of construction have inflated more in Europe than in the United States.

Interest Charges During Construction. Prime interest rates have risen dramatically over the last 20 years.

Exchange Rate Devaluation. Table A-16 has been used for conversions from local currencies into U.S. dollars for a particular year throughout this report. As an example with everthing else constant, devaluation alone would cause a $10,000,000 Swiss plant in 1963 to be $21,000,000 in 1977.

Corrosion Protective Equipment Designs. The problem of metal wastage is elaborately discussed in the report. Spending money for features to reduce corrosion and erosion generally increases investment. A later table identifies 33 features that could be included to reduce metal wastage rates.

Architecture and Landscaping for Neighborhood Acceptance. As close-in European land has become more precious, the few remaining spaces near the city's core are often in household neighborhoods or near major highways. The compromise with local citizens has occasionally been to promise a beautiful plant surrounded by exceptional landscaping. This can significantly increase costs.

The two almost identical Copenhagen plants, each originally with a 864 ton per day capacity, had very different capital costs. Granted not all of the variance can be explained by the aesthetic budget for architecture

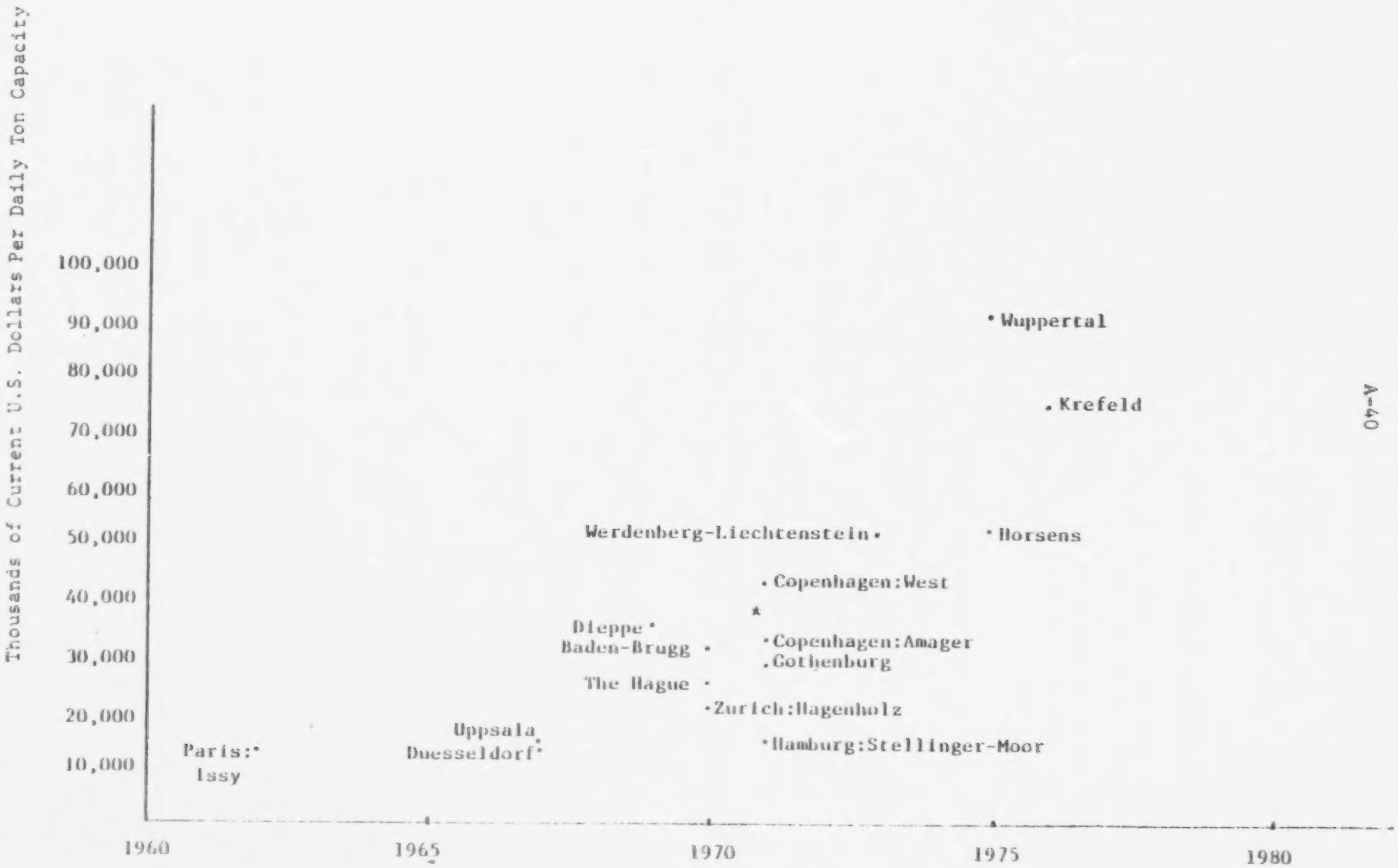


Figure A-10. CAPITAL COST PER DAILY TON CAPACITY

*Average

TABLE A-16. EXCHANGE RATES FOR SIX EUROPEAN COUNTRIES, (NATIONAL MONETARY UNIT PER U.S. DOLLAR) 1948 TO FEBRUARY, 1979[(a)]

	Denmark Kroner (D.Kr.)	France Francs (F.Fr.)	W. Germany Deutsch Mark (D.M.)	Netherlands Guilders (Gl.)	Sweden Kronor (S.Kr.)	Switzerland Francs (S.Fr.)
1948	4.810	2.662	3.333	2.653	3.600	4.315
1949	6.920	3.490	4.200	3.800	5.180	4.300
1950	6.920	3.499	4.200	3.800	5.180	4.289
1951	6.920	3.500	4.200	3.800	5.180	4.369
1952	6.920	3.500	4.200	3.800	5.180	4.285
1953	6.920	3.500	4.200	3.786	5.180	4.288
1954	6.914	3.500	4.200	3.794	5.180	4.285
1955	6.914	3.500	4.215	3.829	5.180	4.285
1956	6.914	3.500	4.199	3.830	5.180	4.285
1957	6.914	4.199	4.202	3.791	5.173	4.285
1958	6.906	4.906	4.178	3.775	5.173	4.308
1959	6.908	4.909	4.170	3.770	5.181	4.323
1960	6.906	4.903	4.171	3.770	5.180	4.305
1961	6.886	4.900	3.996	3.600	5.185	4.316
1962	6.902	4.900	3.998	3.600	5.186	4.319
1963	6.911	4.902	3.975	3.600	5.200	4.315
1964	6.921	4.900	3.977	3.592	5.148	4.315
1965	6.891	4.902	4.006	3.611	5.180	4.318
1966	6.916	4.952	3.977	3.614	4.180	4.327
1967	7.462	4.908	3.999	3.596	5.165	4.325
1968	7.501	4.948	4.000	3.606	5.180	4.302
1969	7.492	5.558	3.690	3.624	5.170	4.318
1970	7.489	5.520	3.648	3.597	5.170	4.316
1971	7.062	5.224	3.268	3.254	4.858	3.915
1972	6.843	5.125	3.202	3.226	4.743	3.774
1973	6.290	4.708	2.703	2.824	4.588	3.244
1974	5.630	4.444	2.410	2.507	4.081	2.540
1975	6.178	4.486	2.622	2.689	4.386	2.620
1976	5.788	4.970	2.363	2.457	4.127	2.451
1977	5.778	4.705	2.105	2.280	4.670	2.010
1978						

(a) Exchange Rate at end of period.

Line "ae" Market Rate/Par or Central Rate.

Source: International Financial Statistics: 1972 Supplement; Volume XXXI, No. 4, Published by the International Monetary Fund.

and landscaping, but aesthetics were the major cause. Amager, located on land recovered from the sea in an industrial area, has a $32,604 per daily ton figure while the more aesthetically pleasing West plant located at a major highway intersection in a residential neighborhood costs $42,434 per daily ton.

More Complex Energy Use Systems. Some newer systems maximize energy effficiency by having a back-pressure electricity turbo-generator consuming high pressure steam and exhausting low pressure steam. This is then used in district heating schemes requiring miles of pipelines. As the price of energy continues to rise there will be more pressure for cogeneration and other complex capital-intensive energy schemes.

The single line 132 ton per day plant at Werdenberg-Liechtenstein producing 0.5 Mw electricity, industrial process steam and district heating hot water is the prime example of an overly complex energy scheme considering the volume of waste consumed.

More Air Pollution Control Equipment. Environmental regulations have continued to tighten. The two highest capital investment cost per daily ton plants in the survey are Wuppertal ($89,582/Ton) and Krefeld ($73,905/Ton). Both plants came under the new source performance standard of the new West German regulation "T. A. Luft". In contrast to the United States, each new West German refuse burner must have a wet scrubber or equivalent to collect HCl and HF gases. The Krefeld plant also has a second stage scrubber to collect SO_2 to help meet ambient levels.

There has been minimal interest expressed so far by the other European, the Canadian and the U.S. Environmental Protection Agencies for control of HCl, HF and SO_2 from refuse burners.

Expenses

In 1976, the average plant surveyed processed 195,790 tonnes (215,369 tons) per year of 536 tonnes (590 tons) per day. The average total expenses were $27 per ton as summarized in Table A-17.

There should be no doubt about the capital intensive nature of refuse fired steam and hot water generators. Operations and maintenance accounts only for slightly over a third of total costs.

The numbers have been recalculated a second time without the very small Werdenberg-Liechtenstein plant (a single 120 tonne/day line) data. Not using this data point reduces the total expenses to $24.33 per ton in 1976.

Economies of Scale. While conducting thhe interviews, these researchers began to feel that there were no economies of scale in these wastes-to-energy plants. With the Werdenberg-Liechtenstein exception, there seemed to be no effect of plant capacity on total expenses per ton of refuse processed.

With this suspicion, Figure A-10 was generated showing total expenses per year versus annual tonnage. The data appeared to be linear. Deviations from the straight line were easily explainable in each facility as shown in the figure.

To plot the same information but in a different manner, Figure A-11 was

TABLE A-17. SUMMARY OF EXPENSES FOR 15 EUROPEAN REFUSE TO ENERGY SYSTEMS

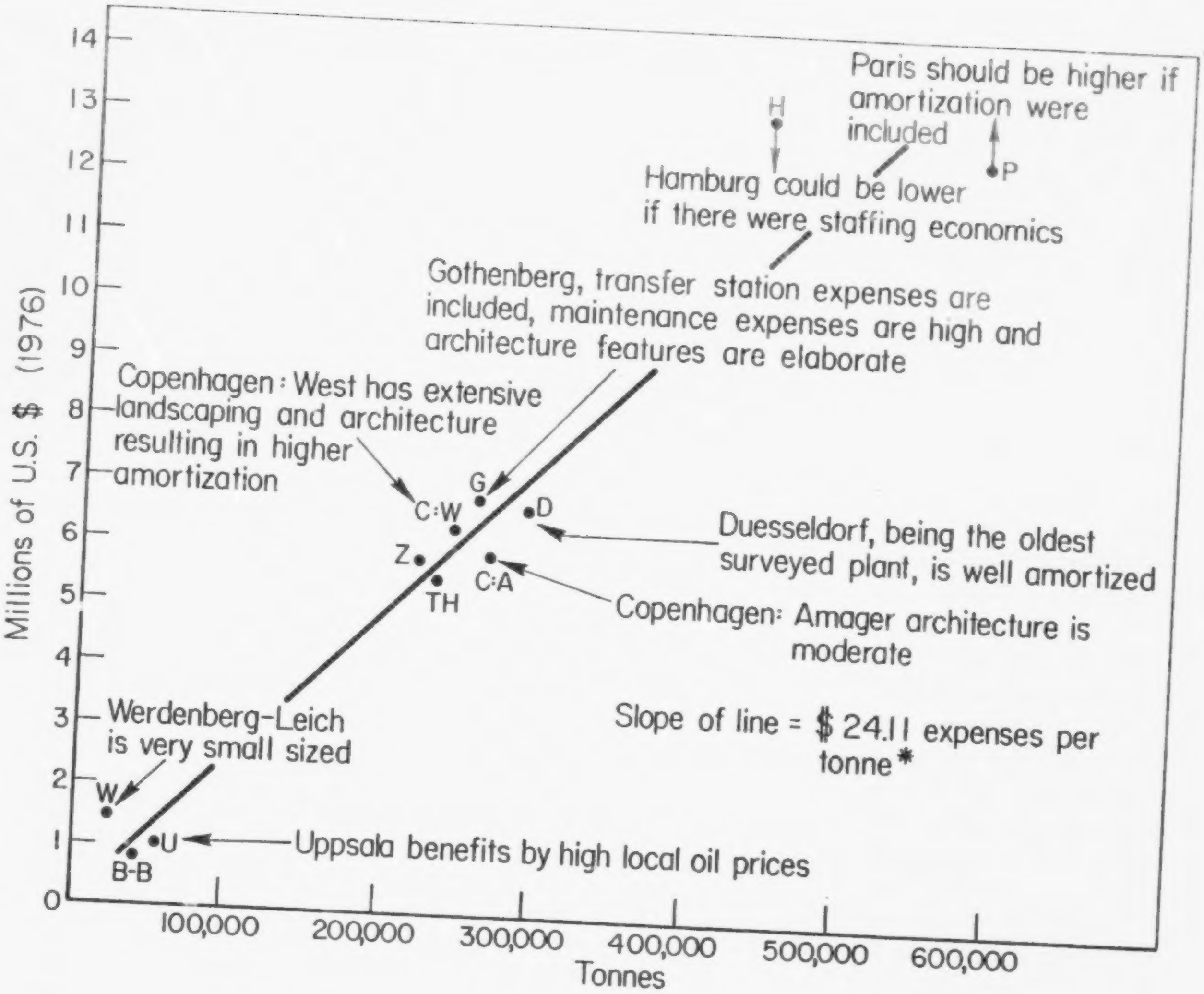
	1976 U.S. Dollars per Short Ton											Expenses Without Interest, Depreciation And Contribution To Reserve		
	Operations & Maintenance Labor & Materials	Residue Disposal	Admin-istration	Insurance and Taxes	Misc. Expenses	Interest and Depreciation	Contribution to Reserves	Total Expenses	Year Operations Began	Tonnes Per Year	Total Expenses U.S. $	Total	Per Ton	
Werdenberg-Liechtenstein	14.70	1.84	0.19	1.08	1.22	35.61	0.00	54.64	1974	26,018	1,564,786	495,000	14.03	a
Baden-Brugg	10.48	1.47	0.13	0.43	0.02	8.38	4.34	25.25	1970	41,693	959,000	522,000	12.52	
Duesseldorf	9.86	0.15	0.37	0.15	0.89	8.10	0.00	19.52	1965-72	297,359	6,385,000	3,396,000	11.42	
Wuppertal									1976	178,000				
Krefeld									1976	114,000				
Paris:Issy	6.64	0.29	1.50		1.10				1965	588,904		5,612,000	9.53	
Hamburg:Stellinger-Moor	14.95				2.50	11.02	0.00	28.47	1972	420,680	13,174,000	7,341,000	17.44	b
Zurich:Hagenholz	4.06	2.28	0.52	0.20	1.54	15.31	0.00	23.91	196 -73	223,595	5,881,000	1,923,000	8.60	
The Hague	9.88	1.12				10.43	0.00	21.43	1968-71	229,000	5,398,000	2,519,000	11.00	
Dieppe									1974	14,892				
Gothenburg	7.16	0.27	3.09		9.01	7.98	0.00	27.51	1970	242,536	7,339,000	4,737,000	19.53	c
Uppsala	10.09		0.98			6.55	1.81	19.43	1970	52,040	1,009,000	576,000	11.07	
Horsens									1974	18,909				
Copenhagen:Amager	5.94	0.99	0.58	0.63	2.47	9.50	2.25	22.36	1970	255,000	5,641,000	2,706,000	10.61	
Copenhagen:West	6.97	0.80	0.91	0.68	0.17	14.87	3.64	28.04	1970	234,230	6,287,000	2,232,000	9.53	
AVERAGE ($/ton)	9.16	1.02	0.92	0.53	2.10	12.77	1.20	27.06	1971	195,790	5,363,779	2,914,455	12.75	
Divider "N"	11	9	9	6	9	10	10	10	15	15	10	11	11	
PERCENT (%)	33.85	3.77	3.40	1.96	7.76	47.20	11.12	109.06%*						

* The sum of the average percentages cannot equal 100,000 percent until all of the data cost cells are filled.

a. Unusually high interest and depreciation and O & M

b. Unusually high labor costs

c. Includes 5 transfer station operations



TOTAL ANNUAL EXPENSES VERSUS ANNUAL TONNAGE

*Excludes High Werdenberg–Leichtenstein number

Figure A-11. TOTAL ANNUAL EXPENSES VERSUS ANNUAL TONNAGE

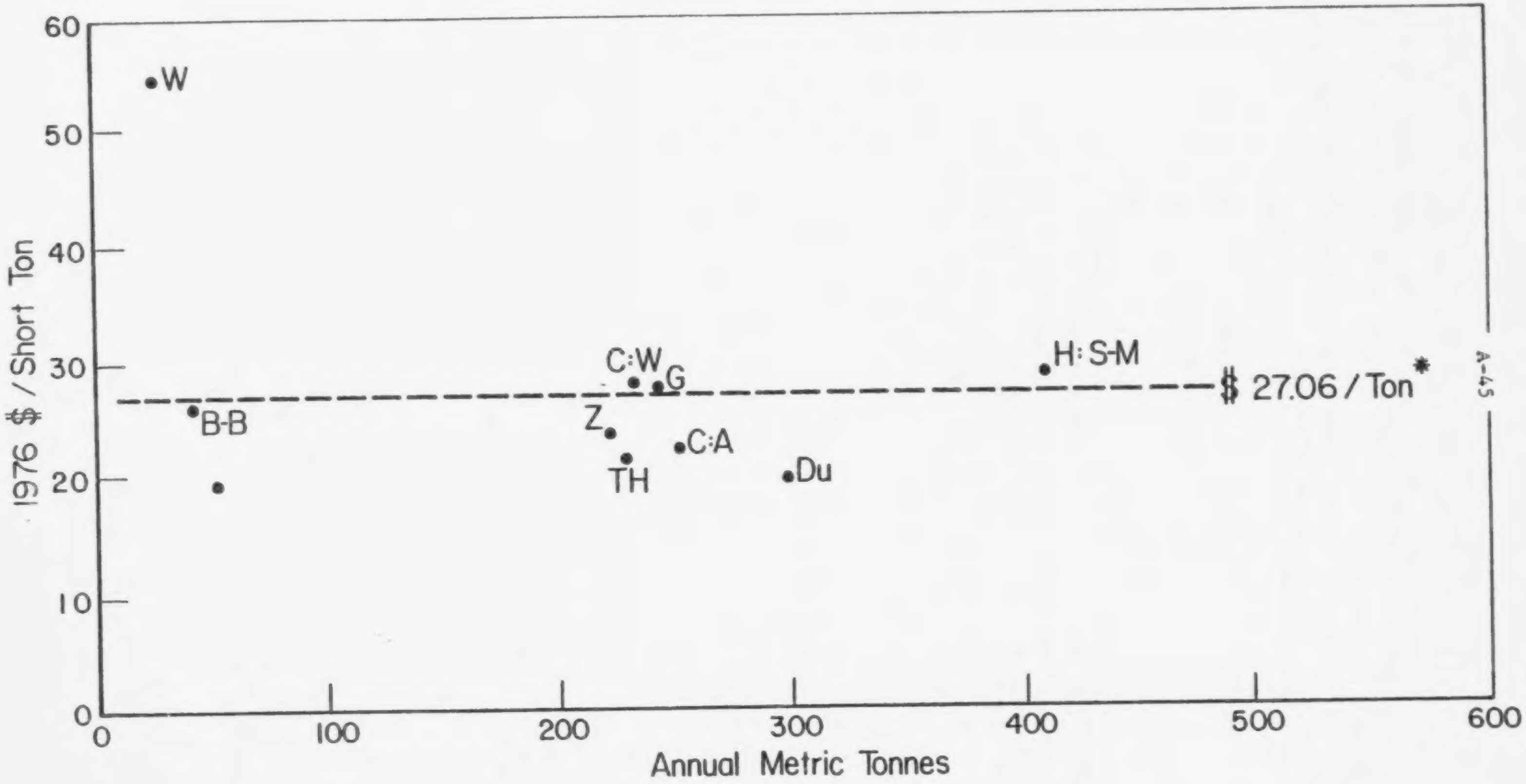
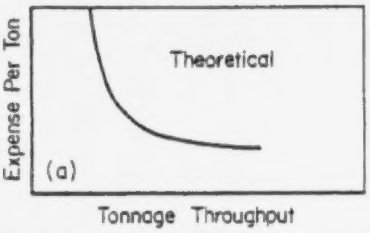
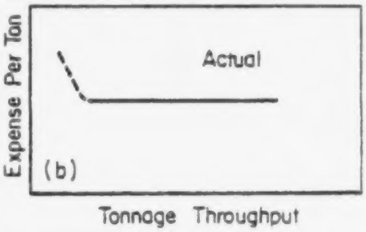


Figure A-12. EXPENSES PER TONNAGE (U.S. $ PER TON) VERSUS ANNUAL TONNES (1976 EXCHANGE RATE)

*Includes High Werdenberg—Leichtenstein number constructed showing U.S. $ expenses per ton versus the annual tonnes throughput. Excluding Werdenberg-Liechtenstein, only a straight horizontal line could be drawn through the points.

Conventional economies of scale theory is represented by the below graph (a). This compares with the actual of graph (b).





Reasons for this observation have perplexed these researchers. The reason seems to be in the thought and action patterns of customers, vendors, engineers, designers, architects - the patterns of those who specify the system. We have observed that the bigger the system, the more "bells and whistles" are added. A common attitude was, "We were building a bigger plant so we could affort to do things the right way". In contrast, "Our plant was so small that we had to take advantage of every cost cutting option available". Some specific examples are given below:

1. The small Baden-Brugg plant has no shear or shredder.
2. The large Duesseldorf plant has both a shear and a shredder.
3. The smaller plant operators walk to the furnace to see how the fire is as the primary means of controlling operations.
4. Martin, in its larger furnaces, not only uses an analog computer "black box" to variably control feed rate but they also install an attemperator between the first and second stage superheater to conto control exit steam temperature to 400 C 5 C.
5. At Werdenberg-Liechtenstein, the plant manager and his wife do all the office work, correspondence and bookkeeping.
6. Yet at Hamburg, there is a staff of office workers at the plant and a cadre of people at the city's central office.

The above are not made as particular criticisms but rather as observations. It seems that an unusual cost between $18 and $30 per ton is the acceptable target.

Revenues

To permit data comparisons, total Expenses are defined to equal total Revenues. Thus theoretically Table A-17 and Table A-18 should have equal expense/ton and revenue/ton figures. However, the average is different: $27.40/ton expenses and $28.43/ton revenues because the plants used in calculating the average are different.

As a gross summary, Table A-19 has been prepared.

Table A-18. SUMMARY OF REVENUES FROM 15 EUROPEAN REFUSE TO ENERGY PLANTS (U.S. 1976 $ PER TON)

	Sale of Scrap Iron and Road Ash	Sale of Energy*		Net Disposal Cost on Tipping Fees	Interest on Reserves	Sludge Destruction Credit	Other Revenues	Total Revenues
Werdenberg-Liechtenstein	0.14	5.80	W,S,E	48.25			0.45	54.64
Baden-Brugg		6.17	E	18.63	0.02		0.43	25.25
Duesseldorf	1.21	9.47	S,E	8.84				19.52
Wuppertal	0.58	7.56	E	35.66				43.80
Krefeld						?		
Paris:Issy	0.26	6.25	S,E	6.27				
Hamburg:Stellinger-Moor		5.92	E	22.55				
Zurich:Hagenholz	0.02	10.11	S,E	12.66			1.12	23.91
The Hague		5.59	E	15.84				21.43
Dieppe						?		
Gothenburg		8.17	W	19.34				27.51
Uppsala		11.70	S	6.83				18.53 (1975)
Horsens		9.37	W	15.21		3.12		27.70
Copenhagen:Amager		3.00	W	16.57	0.63		2.16	22.36
Copenhagen:West	0.15	6.78	W	18.15	2.58	___	0.38	28.04
TOTAL	0.39	7.38	W,S,E	18.83	1.07	3.12	0.91	28.43

*W: Hot Water, S: Steam, E: Electricity.

Table A-19. GROSS SUMMARY OF REVENUE FROM EUROPEAN REFUSE FIRED ENERGY PLANTS

	All Plants*		Without Werdenberg-Liechtenstein	
	$/Ton	%	$/Ton	%
Net disposal cost or tipping fee	18.83	59.4	16.38	55.4
Sale of energy (hot water, steam, electricity)	7.38	23.3	7.51	25.4
Sludge destruction credit	3.12	9.8	3.12	10.6
Interest on reserves	1.07	3.4	1.07	3.6
Other revenues	0.91	2.9	1.02	3.5
Sale of scrap iron and road ash	0.39	1.2	0.44	1.5
Average of Revenues	28.43	100.0	25.81	100.0

*Where adequate data is available.

The net disposal cost or tipping fee (regardless of how collected) has been plotted on Figure A-12 for 13 plants. This figure presents an unclear picture about economics of scale affecting net disposal costs. However, we can state that we believe there are much more important considerations affecting economic results than economics of scale.

Sale of Energy. As a general rule of thumb, American refuse (household, commercial and light industrial waste) will produce a net salable 5,000 pounds steam per ton of reufse while European refuse produces a lower amount, perhaps 4,000 pounds steam per ton of refuse. The typical European (1976) revenue for the sale of energy of $7.51 per ton refuse is equivalent to about $1.88 per million BTU. Many persons have commented that the key reason that the Europeans have developed their refuse-fired energy systems is that the price of energy in Europe was much higher than in the U.S. While this may have been true when some European plants were initially planned, by 1976 incremental U.S. energy prices were much closer to European prices.

Sludge Drying Credit. Of 30 refuse burning systems that Battelle researchers visited, seven systems use the energy in the refuse to dry and/or destroy sewage. However, only at Horsens do we have a clear and separable reported sludge drying credit -- a figure of $3.12 per refuse input ton.

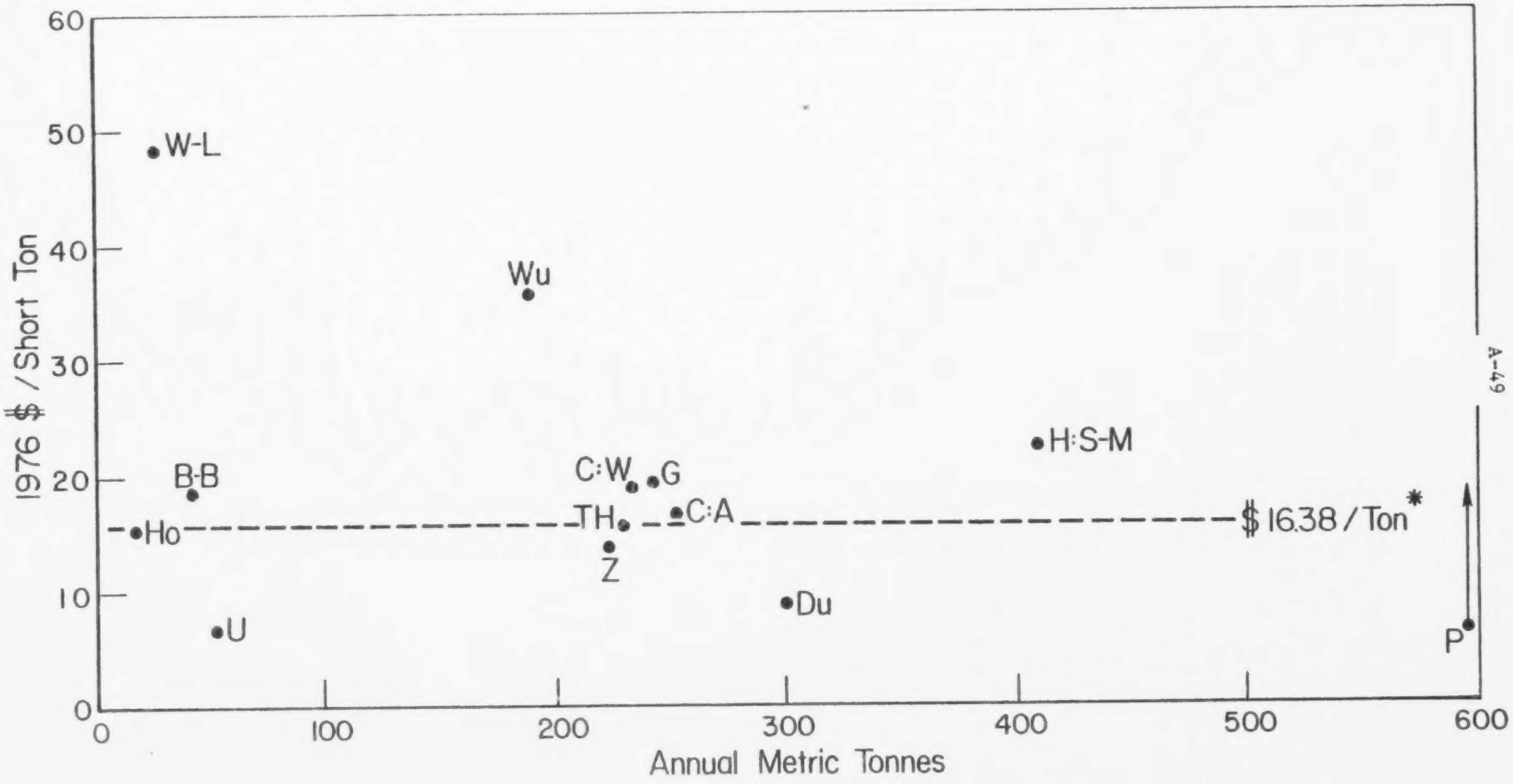


Figure A-13. NET DISPOSAL COST OR TIPPING FEE AT 13 EUROPEAN REFUSE FIRED ENERGY PLANTS

*Excludes High Werdenberg-Leichtenstein number

Sale of Scrap Iron and Road Ash. Ash residue is sold not only for revenue but also to eliminate or reduce the ash disposal landfill expense. Landfill costs will be reduced to about 20 percent of the case where there is no sale of road ash. Therefore, the economist should add the marginal savings when less ash is landfilled to the metal scrap and road aggregate revenue.

Unfortunately we do not have enough economic data to conclude that ash recycling is even marginally beneficial for the average plant. Where the refuse burning plant is located in a steel producing region that needs scrap for a melt or there is a shortage of conventional road aggregate products the economics should be more attractive.

Interest on Revenues. In a few systems more money is collected than spent. This results in Contribution to Reserves which is akin to profit in a private enterprise system and is shown as an expense.

On the revenue side, interest on these previously collected and invested reserves is added in revenues. In a few systems, this figure is surprisingly high. When averaged over four reporting plants, the average is $3.01 per ton. But when averaged over ten plants, the average is $0.91 per ton.

"Contribution to Reserves (expense)" and "Interest on Revenues (revenue)" view is to consider that this public organization, owned by taxpayers, overcharded themselves. This extra recovery can:

- be invested to produce interest revenue which reduces net disposal costs
- be applied to debt reduction
- provide a cushion for addition of a new line or replacement of the entire facility.

Net Disposal Cost or Tipping Fee

To use a business expression, the "bottom line" is the Net Disposal Cost or sometimes the Tipping Fee. This is the resulting cost or burden borne by the citizens, taxpayers and generators of waste. This is the figure used to compare techniccal alternatives for solid waste disposal (compost, landfilling, materials recovery, waste-to-energy, etc.).

This ranges upward from a low of $6.27 per ton at Paris:Issy. However, this is not truly a comparable figure because there is no depreciation expense included in the number. Since the plant is owned by the City of Paris depreciation is not included in the operator's financial statement. Had normal depreciation and interest been included the net disposal cost would be well over $10 per ton.

Low Net Disposal Cost Systems. Uppsala, a refractory walled furnace, (and not a water-tube wall furnace) shows the best net cost at $6.83 per ton for two reasons. First, three of the furnaces are old so t he original capital investment cost to amortize is small. Perhaps some equipment may be fully depreciated already. Then too, many claim that original capital cost and the continuing operations and maintenance costs on the simpler refractory walled low temperature energy systems are inherently lower than the complex water tube wall-high temperature steam systems requiring expensive corrosion protection.

Second, in addition to having the lowest amortization costs, Uppsala has the highest energy revenue per input ton ($11.70) of any visited system. This is due to the revenue formula that parallels the cost of foreign oil, storage costs, 50 mile transport costs and Swedish taxes. The Swedes, not having national energy sources, have traditionally paid more for their energy.

It is interesting to compare at this point this "best" financial result system in our survey with the U.S. system having an excellent net disposal cost. The Babcock and Wilcox - Detroit Stoker refuse fired steam generator and Carrier chiller station energy system in Nashville, Tennessee achieved. A net disposal cost of only $6.41 per ton is a supurb situation for the waste generating public.

Of note is that very slightly more revenue comes from sale of chilled water for district cooling than steam for district heating. While several energy customers have challenged the steam price, the energy is in fact, priced in the mid range of all U.S. district heating systems at $5.90 per 1000 pounds steam. Even with these excellent results, the system only sells 60 percent of the steam it produces. One can only speculate about financial results if cogeneration of electricity in a backpressure turbine were ahead of the chiller station and the district heating and cooling loops.

In addition to the current financial success, the stack emissions are extremely low at 0.005 to 0.01 grains per SCF adjusted to 12 percent CO_2. This compares to the U.S. Federal standard of 0.08 gr/SCF.

Many in this industry remember the previous hopeless situation at the Nashville unit. The combination of original insight by Mayor Briley, the designer I.C. Thomasson, the equipment suppliers and community leaders and the steadfast continuing support from these same community leaders and financial institutions and the strong pressure for clean air from the U.S. EPA has all united in this exemplary American refuse fired steam generator.

A key economic/financial lesson to be learned is that if inflation consumes a previously passed bond issue, go for more money rather than make unjustified compromises in design that will need to be rectified later.

High Net Disposal Cost Systems. Comment should be made on the three highest net cost systems. Werdenberg-Liechtenstein's $48.25 per ton is the highest by far. The vendor knew that the figure would be high and so stated to the community. The community, however, considered its scenic beauty too great to mar with another landfill. In addition, there was a most attractive Swiss federal grant or low interest loan program that encouraged the community to participate. The initial outside funding per capital investment apparently was emphasized more than the long term net disposal fees needed to support annual costs.

We suggest that the use of Federal and state funding to further the objectives of resource recovery take into account the discount ed long term effects of participation. An analogy might be the wealthy father who helps his 17 year old son buy an expensive Corvette automobile only to later learn that the son cannot pay the $500 per year insurance premium.

A specific reason for the high cost at Werdenberg is that costs must be divided by only 120 ton per day. This is the only plant surveyed that we can clearly say suffers from diseconomies of scale. A single 120 tonne, (132 ton) per day line with standby energy backup is too small. This is especially small considering the diverse energy uses (hot water for district heating, steam for the chemical plant and electricity for the network).

Wuppertal with a $35.66 per ton net disposal cost is adversely affected today because of concern for the future capacity. Of its four furnaces, one is always down because of lack of refuse. A second unit is usually down for preventive maintenance or repairs. Thus the total costs for this sophisticated electrical generating plant with four lines must be supported with the activity in only two lines. Planners in other situations would have built 3 units and left an open bay for a later 4th. Perhaps refuse input from a neighboring community will increase operations and spread fixed expenses over more tonnage.

The Hamburg:Stellinger-Moor system at $22.55 per ton has unusually high labor costs. The cost of $14.95 per ton for operations and maintenance labor and materials was the highest in the survey. A second observation was that the revenue of $5.92 per ton from sale of electricity is a bit low.

One Medium Net Disposal Cost System of Special Note. Zurich:Hagenholz achieved very reasonable results at $12.66 per ton for several reasons. Frankly the professional administrative spirit of the Director is to be highly credited. A spirit of pride and efficiency pervades all activities. Job positions must continually be justified. Total operations and maintenance labor and materials was only $4.06 per ton, the lowest in the survey. Comparatively, the interest and depreciation is high at $15.31 per ton. This is consistent with management's emphasis favoring purchase of what they consider to be the best equipment to reduce labor and material needed for operations and maintenance. Thirty-three (33) separate design and operation decisions were identified specifically to reduce corrosion. As a result, the superheater tubes have suffered only 0.3 mm (0.012 in) metal wastage in five or six years. Other tubes have lost only 0.1 mm (0.004 in) in the same 30,000 hours. This is remarkable and has proven that high temperature steam, 788 F, can be produced at a reasonable price with virtually no corrosion if proper design and operation decisions are made and carried through.

Battelle staff have attempted to analyze the wide variation in results, $6.27 up to $48.25 per ton, by manufacturer or prime vendor. While averages can be derived and arrayed, we feel that the local situations far outweigh vendor importance. Besides that, our sample of only two or three plants per vendor is not enough to develop significant conclusions.

However, it should be pointed out that each of the four refractory wall systems performed better than the survey average. Yet the two surveyed manufacturers have yet to mount an effective North American marketing effort in recent times. At this writing, Summer 1979, Bruun and Sorenson has no North American representative. Volund has appointed a new representative in Chicago, Waste Management, Inc.

It is our opinion that American resource recovery competitions would benefit by marketing efforts also from European and North American manufactures of refractory wall incinerator-waste heat recovery boiler vendors.

Finance

Table A-21 presents modes of financing. There was no real financial pattern between countries. In all cases, the plants were built and financed by the municipality or solid waste authority. This includes Issy, operated by T.I.R.U. but owned by the City of Paris and also Dieppe operated by I.N.O.R.-Thermical but owned by the City.

The availability in America of tax free bonding for private enterprise to develop public service environmental services will continue to affect not only detailed financing decisions but also basic decisions about ownership and operations. The long term financing options in America will likely encourage more privately owned systems than are possible in Europe.

Of note was that the vendor VKW at Wuppertal and I.N.O.R.(Von Roll) at Dieppe made modest company loans to the customer for purchase of scrubbers, a crane, a weigh station, furniture, an ash truck, etc. None of that which was financed was a "manufactured product" of these two companies.

The only relatively common mode (7 plants out of 15) of finance was to use the bank loan.

System Ownership and Governing Patterns

Private enterprise owned none of the 30 systems visited. In all cases solid waste disposal and resource recovery are public matters. Of the 15 plants studied in detail, operation was turned over by the City to another organization in 2 cases.

Personnel Categories

Over 120 job titles are discussed in the body of the report. In no way is it recommended that any plant have all of these jobs.

It was observed that larger plants tend to have larger staffs, including many jobs not found at smaller plant. Potential economies of scale from the larger plant are often nullified by a large staff. This observation holds true not only for managerial functions but also operations personnel.

Rather than hire permanent employees, many plants use outside services extensively.

Education, Training and Experience

Training varies widely among countries. Germany seems to have the most rigorous program. This usually involves schooling, navy or merchant marine boiler room experience, more schooling, more sea experience, etc., for up to 16 years. Often between ages 30 and 40, a man will leave the sea to become a stationary power boiler operator. Eventually he may move to a refuse fired energy plant.

Switerland, a landlocked nation, often uses former employees of Brown Boveri, Sulzer, etc., who make or install power systems around the world.

Refuse Handling

Weighing of Refuse Received

Considerable attention is usually given to measuring the amount of waste received. Many of the plants visited use automatic recording of loaded truck weight as it arrives at the plant, and many truck drivers carry a coded identification card to be inserted into the card slot at the scale at the time of weighing.

Many of the plants experienced early difficulty with failure of the electronic system at the scales. In most cases these initial problems have been cleared up by the scale manufacturer. However, the electrical system usually requires frequent maintenance. A few large plants use 2 scales for redundancy and to handle peak loads without causing long lines of waiting trucks. One plant uses a separate scale to weigh the residue from the furnaces. Most scales are recalibrated once every year or two.

At very small plants the scale operation is observed and controlled by the crane operator who sits at the plant control board. In such instances the main control room is located in such a way that the busy operator can view the trucks discharging to the pit. In some cases he can also observe the distant tipping floor by means of closed-circuit television.

In the larger plants the weighing operation is controlled by 1 or 2 scale operators who also direct the truck traffic through amplified voice instructions and sometimes by means of red and green signal lights.

At most plants it is the duty of the scale operator to detect bulky items and to instruct the driver to deposit them in a separate collection place.

Tipping Floor, Pit and Crane

The universal European practice for receiving, storing, and feeding the solid waste to the furnaces is the ancient pit and crane system. To some new to the field this method appears incredibly archaic. However, it has so far satisfied European needs, and efforts to supplant it with modern conveying equipment have not succeeded. The major barriers to change is the heterogeneity of MSW, its strong tendency to densify when stored, and its occasional hazardous nature.

At most of the plants visited the tipping floor is indoors. In most cases, indoors or outdoors, the discharge openings into the pit are covered by power-operated doors. Thus pit odor is kept inside by fresh combustion air flowing through the open doors under the action of the combustion air blowers. In most cases the blowers take the air from filtered air intakes near the top of the pit. Thus air flow is always inward and in no case was the odor of refuse detected outside the plants nor in the neighborhood.

In most plants the entrance and egress of the trucks to the tipping area is controlled by the scale operator, with a workman on the tipping floor controlling the opening and closing of the pit doors. In a few cases the hydraulically lifted doors are operated by the truck driver.

Refuse pit storage volume, dimensions and capacities are presented in Table A-20.

TABLE A-20. REFUSE PIT STORAGE VOLUME, DIMENSIONS AND CAPACITIES

	Plant Design Capacity tonnes/ day	Nominal Plant Oper. tonnes/ day	BUNKER VOLUME Level Full M^3	yds^3	Maximum M^3	yds^3	BUNKER DIMENSIONS Length M	Width M	Depth M	Length ft	Width ft	Depth ft	STORAGE CAPACITY(2) At Packed Density of 645lb/yd^3 (383Kg/M^3) Level tonnes	Max tonnes	Tons	Days Supply At Full Plant Capacity	Days Supply At Nominal Plant Capacity
Werdenberg	120	100	1300	1640	--	--	20	7.5	8.5	65.6	24.6	27.9	500	--	550	4	5
Baden-Brugg	200	160	2600	3400	--	--	23.4	8.4	14.1	76.7	27.6	45.3	995	--	1095	5	6
Duesseldorf	1260	960	10,500	13,734	--	--	--	--	--	--	--	--	4022	--	4424	3	4
Wuppertal	1440	1080	10,000	13,080	18,000	23,540	--	--	--	--	--	--	--	6894	7583	5	6
Krefeld	576	576	6,000	7848	9000	11,772	35.0	12.0	--	115	40	--	--	3796	4175	6	6
Paris:Issy	1632	1550	--	--	--	--	--	--	--	--	--	--	--	5000	5500	3	3
Hamburg:SM	1180	--	10,400	13,600	10,400	13,600	54	12	16				3970	--	4370	3	--
Zurich: Hagenholz	1024(1)	--	5000	6540	9000	11,770	--	--	--	--	--	--	1920	3456	2100	3	--
The Hague	1440	1080	10,000	13,080	16,000	20,930	--	--	--	--	--	--	--	6100	6710	4	6
Dieppe	120	63	750	980	--	--	--	--	--	--	--	--	290	--	320	2	5
Deauville	120	--	700	920	--	--	--	--	--	--	--	--	270	--	295	2	--
Gothenberg: Savenah	1080	900	6000	7843	12,000	15,690	--	--	9	--	-- --	30	2300	4600	2530	2	3
Uppsala	348	200	--	--	2400	3140	--	--	--	--	--	--	--	920	1010	3	4
Horsens	120	67	950	1240	--	--	--	--	--	--	--	--	360	--	400	3	5
Copenhagen: Amager	864	864	10,000	13,080	20,000	16,160	48	17	13	157	56	43	6100	12,200	6710	7	7
Copenhagen: West	1152	864	12.500	16,350	25,000	32,700	56	17	13.5	184	56	44	7625	15,250	8390	6	9

(1) Nominal capacity included 2 older units.

(2) This assumed density would apply after several days'storage.

Usually the drivers are expected to clean up any spilled refuse before they leave and, in general, the tipping floors were free of debris, but not always. The attitude of management toward housekeeping standards was variable and resulted in very few messy tipping floors. One plant, Wuppertal, made daily use of a large mobile washer and sweeper to keep the tipping floor and adjacent ramps exceptionally clean.

Pit Doors

The most commonly used powered pit door is the multi-hinged door. A distinct disadvantage of this type is that if several such doors happen to be open at once at a busy time the lifted doors hide much of the pit from the view of the crane operator who is many times situated directly above the doors. Also such doors projecting into the crane area are very vulnerable to accidental collision with the crane bucket. For these reasons the new Zurich Josefstrasse plant.

Pit or Bunker

The floor of most pits is below grade. Because of water-table or excavation problems, a few are at grade, in which case the tipping floor is elevated and is reached by a sloping sometimes helical, ramp. Most pit walls are reinforced concrete.

The predominant design philosophy provides a maximum pit storage capacity of 4 to 5 days' operations. Since all of the larger plants usually schedule one unit to be down for maintenance, the actual storage capacity provides for 5 or 6 days of normal plant operation.

Pit fires are usually controlled by sprinkler systems and water guns controlled by the crane operator. For extremely dry, industrial waste at The Hague, there is a separate pit in which water sprays operate most of the time to reduce the heat value of the refuse as fired. This prevents fires and also avoids overheating of the boilers which were designed originally for wet municipal solid waste.

Crane

The larger plants have 2 cranes which provide redundancy. The almost universal comment was that the crane operator is the most important worker in the plant. A skilled operator will divert troublesome bulky items to avoid problems in the furnace and will mix segregated, highly combustible wastes in the pit so as to avoid excessive heat release in the furnace. Also his skill is very important in extending the life of the crane cables which can become kinked and twisted in the process of retreiving batches of waste from the pit.

In most small plants the crane operator performs from a glass-walled podium at one side of the control room positioned so as to provide a view of the tipping area, pit and furnace hoppers. In the larger plants the separate podium is situated high in the wall above the pit often the podium has dual controls and is lavishly equipped above the pit. In no case did the crane operator ride the crane, although this is common in American plants.

Bulky Waste Size Reduction

Few plants have size reduction equipment. The most used shear is manufactured by Von Roll. The bulky waste shears operate like multiple sissors, cutting and crushing the bulky refuse between its shear beams. Seven fixed and six moveable shear beams are connected at their lower end through shaft and bearings. Each beam is equipped with double edge blades of highly wear-resistant alloy steel which can easily be turned once and reused. The moving beams are arranged in two groups of three, each group being opened and closed by a hydraulic working cylinder.

The sheared material falls through the spaces between the fixed and shear beams and down into the pit. The crane operator must then carefully distribute this usually higher calorific waste over the entire pit.

Hoppers and Feeders

An integral feature of the pit-and-crane system is that each furnace receives its waste from a hopper and chute which are fed intermittently by the crane bucket. This intermittent batch feeding is converted to nearly uniform flow to the furnace-grate by 2 factors:

1. Short-term storage capacity of the hopper and chute
2. Action of a reciprocating or vibrating feeder which moves the refuse from the chute to the grate.

The feeder serves a multiple purpose. In addition to supplying fuel to the furnace its action in moving packed refuse away from the bottom of the chute permits the crane operator to keep the chute packed full. This packed mass served to prevent burn-back from the furnace into the chute and hopper.

At times the crane operator may be so busy with multiple problems of receipts, mixing and charging that some chutes may inadverdently become emptied. If so, burn-back into the feed chute can occur. Accordingly many chutes are equipped with gates or dampers that can be closed to prevent flames from flowing upward through the chute and hopper. Some newer chutes are equipped with radioactive level indicators which provide indication in the control room and crane pulpit when the refuse level is low.

Because of the potential for burn-back causing overheating of the feed chute, some chutes are water cooled or refractory lined.

Grates and Primary Air

The grates used in the early stages of mass burning of refuse were adapted from coal burning practice, the principal change being to provide much more fuel-bed agitation. This was needed because refuse is so heterogeneous that discontinuities and gaps are always present and new ones can form as the refuse burns. Agitation of the bed is the means used to shuffle, tumble, or resettle the burning fuel so as to fill the gaps and make it more uniform for better distribution of primary air and of burning.

Design primary air pressures at visited plants are shown in Table A -21.

Grate Life

In most of the plants visited, the annual cost of grate maintenance was a minor cost but the range of replacement required was considerable. Table A-22 shows the grate-bar replacement experience.

In addition to grate bar replacement, some grates require periodic cleaning to keep the air-flow openings free. Melted aluminum and other metals and mixtures require periodic shut-down for cleaning. For example, at the Horsens plant, the original grate bars required 2 man-hours per week for cleaning which was done during regular week-end shutdowns. Use of a newer design of grate bar has reduced the cleaning required to every other week.

Grate Materials

Because of the frequent exposure of the grate bars to burning material, the bars are usually made of high-chromium content cast steel. However, the Duesseldorf roller grate is primarily of cast iron with only the wear sections at the sides made of cast chrome-nickel alloy. Also, the Volund grate is made of heat resistant Meehanite, a specific form of grey iron casting.

Grate Action

As can be seen in descriptions of potential grates, there is a wide range of concepts for achieving motion of the heterogeneous mass of burning refuse.

Almost all furnaces have a ram-type refuse feeder to achieve positive entry of refuse onto the grate. However, some of the systems depend, instead, on the slope of the grate. The grate bar motion then ensures movement of the refuse along the grate surface. Virtually all grates are steeply sloped, up to 30 degrees. But one is not--K&K--which, under one of its configurations, deliberately holds the refuse horizontally while agitating it along by reciprocating grate motion.

All grates observed provide agitation of the burning mass. This is in recognition of the need to do two things:

- Continually expose fresh surfaces to ignition and air flow
- Keep filling in voids that form rapidly when zones of lightweight highly combustible material burn out. This leaves voids through which primary air can bypass the bed unless such holes are promptly filled by rearrangement of the heterogeneous mass.

Even the older traveling grate which provides no fuel bed agitation was installed as a multiple series of stepped traveling grates so that as the burning refuse tumbled from one grate down to the next, there was momentary agitation and rearrangement of the bed.

Grate dimensions are shown in Table A-23 Table A-24 follows with the burning rates.

Table A-21. DESIGN PRESSURE OF PRIMARY AIR SYSTEM AT PLANTS VISITED

		Primary Air Pressure		
Plant		mmH_2O[5]	in.H_2O[5]	kPa[3]
1	Werdenberg-Liechtenstein	170	6.7	1.67
2	Baden-Brugg	280	11	2.74
3	Duesseldorf	180	7	1.74
		240	4.5	2.37
4	Wuppertal	140	5.5	1.37
5	Krefeld	300	11.8	2.94
6	Paris:Issy	410	16.1	4.00
7	Hamburg:Stellinger-Moor	530	21	5.23
8	Zurich:Hagenholz	580	23	5.72
9	The Hague	370	14.4	3.585
10	Dieppe (and Deauville)	150	5.9	1.471
11	Goteborg	400	15.7	3.91
12	Uppsala	-	-	-
13	Horsens	200	7.9	1.97
14	Copenhagen:Amager	230	9.0	2.24
15	Copenhagen:West	230	9.0	2.24

Table A-22. GRATE BAR REPLACEMENT

Trip		Year Operations Began	Grate Bar Replacement Rate
1	Werdenberg-Liechtenstein	1974	None in three years
2	Baden-Brugg	1970	---
3	Duesseldorf	1965 1972	Three rolls out of 35 in 12 years
4	Wuppertal	1976	None. Clean two times/yr.
5	Krefeld	1976	None. Clean two times/yr.
6	Paris:Issy	1965	60 to 70 bars/yr out of 900 per furnace
7	Hamburg:Stellinger-Moor	1972	24 per cent replacement/yr of all grate bars
8	Zurich:Hagenholz	1973	Seven per cent replace/yr of all grate bars
9	The Hague	1968	None except annual removal of sliding support plates
10	Dieppe (and Deauville)	1971(76)	One half of grate replaced over 7 years
11	Goteborg	1970	60-70 per cent of grate replaced in first five years (Total cost $50,000 -$60,000)
12	Uppsala	1961	Replaced one of three grate sections over 16 years
13	Horsens	1974	20 out of 720 bars replaced per year
14	Copenhagen:Amager	1970	Estim. 100% bar replacement every 15,000 hours
15	Copenhagen:West	1970	Estim. 100% bar replacement every 20,000 hours

Table A-23. GRATE DIMENSIONS

Trip		Year Started	No. of Boilers	Mfg. of Grates	Grate Dimensions						No. of Separate Grate Sections	No. of Parallel Grate Runs
					Width		Length		Area			
					m	ft	m	ft	m2	ft2		
1 Werdenberg-Liechtenstein		1974	1	A-F	2.77	9.1	6.65	21.8	18.42	198.3	1	1
2 Baden-Brugg		1970	2	A-F	2.5	8.2	7.5	24.6	18.75	201.8	1	1
3 Duesseldorf	Boiler 1-4	1965	4	VKW	3.5	11.5	11.0	36.0	38.7	416	7	1
	Boiler 5	1972	1	VKW	3.5	11.5	10.7	35.1	37.6	400	6	1
4 Wuppertal		1976	4	VKW	3.5	11.48	10.2	33.5	35.7	384	6	1
5 Krefeld		1976	2	VKW	3.5	11.48	10.2	33.5	35.7	384	6	1
6 Paris:Issy		1965	4	M	6.3	20.66	8.4	27.6	52.9	569	1	3
7 Hamburg:Stellinger-Moor		1972	2	M	4.7	15.6	8.9	29.3	43.9	472	1	2
8 Zurich:Hagenholz		1973	(1)	M	5.5	18.0	8.4	27.6	44.9	483	1	3
9 The Hague	Boiler 1-3	1968	3	VR	3.0	9.8	10.5	34.0	31.5	339	3	1
	Boiler 4	1971	1	VR	3.4	11.1	12.0	39.4	40.8	439	3	1
10 Dieppe(and Deauville)		1974										
		1976	2	VR	2.0	6.6	8.0	26.2	16.0	172	2	1
11 Goteborg		1970	3	VR	3.4	11.1	10.9	35.8	36.9	397	3	1
12 Uppsala		1970	(1)	B&S	2.0	6.5	8.1	26.6	16.2	174	1	1
13 Horsens		1974	1	B&S	2.0	6.5	8.1	26.6	16.2	174	1	1
14 Copenhagen:Amager		1970	3	V	2.7	8.9	7.0	23.0	18.9	203	2	1
15 Copenhagen:West		1970	3	V	2.7	8.9	7.0	23.0	18.9	203	2	1

*Manufacturer abbreviations: A-F(Alberte-Fonsar); VKW(Vereinigte Kasselworke); M(Martin); VR(Von Roll); B&S(Bruun & Sorensen); V(Volund).

(1) Describes only the last furnace - boiler line purchased.

TABLE A-24. GRATE BURNING RATES

Trip		Rated Refuse Input		Max Rate		Design LHV			Design Burning Rate		Design Grate Heat Release Rate		
		mt/h	t/h	mt/h	t/h	Kcal/Kg	KJ/Kg	Btu/lb	Kg/m^2-h	lb/ft^2-h	$Kcal/m^2$-h	MJ/m^2-h	Btu/ft^2-h
1 Werdenbarg-Liechtenstein		5	5.12	6.4	7.0	2800	11,724	5040	271	55.6	759,920	3182	280,224
2 Baden-Brugg		3.33	3.66	5.0	5.5	2600	10,886	4680	266	54.6	691,600	2895	255,528
3 Duesseldorf	Boiler 1-4	10	11	-	-	1850	7,746	3330	258	52.8	478,000	2001	176,300
	Boiler 5	12.5	13.75	-	-	2111	8,835	3800	332	68.1	702,000	2940	259,000
4 Wuppertal		15.0	16.5	-	-	2250	9,421	4050	420	86.2	945,000	3955	348,500
5 Krefeld		12.0	13.2	-	-	2250	9,412	4050	336	68.8	756,000	3165	278,813
6 Paris:Issy		17.0	18.74	19.9	21.9	1800	7,537	3240	321	65.7	578,520	2422	212,868
7 Hamburg:Stellinger-Moor		18.8	20.6	24.8	27.2	1800	7,537	3240	427	87.3	768,600	3210	282,852
		24.6	27.1	24.8	27.2	1500	6,281	2700	560	114.6	840,000	3517	309,420
8 Zurich:Hagenholz		21.0	23.1	-	-	2300	9,630	4140	468	95.6	1,075,710	4504	395,784
9 The Hague	Boiler 1-3	15.0	16.5	-	-	1800	7,537	3240	476	97.3	856,800	3587	315,252
	Boiler 4	15.0	16.5	-	-	2300	4,630	4140	367	75.2	844,000	3534	311,328
10 Dieppe(and Deauville)		2.8	3.1	3	3.3	2000	8,374	3600	175	35.8	350,000	1465	128,930
11 Goteborg		12.5	13.8	15.0	16.5	2500	10,468	4500	339	69.0	847,500	3548	310,500
12 Uppsala		5.0	5.5	-	-	2450	10,258	4410	309	63.1	757,050	3170	278,271
13 Horsens		5.0	5.5	-	-	2800	11,724	5040	309	63.1	865,200	3623	318,024
14 Copenhagen:Amager		12.0	13.2	13.0	14.3	2000	8,374	3600	635	130.0	1,270,000	5317	468,177
15 Copenhagen:West		12.0	13.2	13.0	14.3	2000	8,374	3600	635	130.0	1,270,000	5317	468,177

Three basic grate systems are used as shown in Figure A-13. There are many other variations of these three types.

This particular contract between Battelle and EPA is to concentrate on European refuse burning to energy systems. As such all systems viewed have been mass-burning grate systems. To our knowledge there was only one system in Europe (Birmingham, England) burning refuse in suspension --- in contrast to U.S. developments.

Table A-25 presents a listing of independently developed refuse burning systems, their home country and their American representative "Refuse burning" refers to "combustion" or "incineration" where combustion products after a few seconds are H_2O, CO_2, SO_2, etc. There is no attempt to present manufacturers of pyrolysis or other developmental resource recovery processes, i.e. this is not a full list of resource recovery manufacturers. Also excluded are the many manufacturers of small modular package incinerator-heat exchangers. The table includes present and past manufacturers with heat recovery.

Manufacturers of only incinerators (without boilers to cool combustion gases prior to gas cleaning) are not included in the listing.

Grate Functions

The three primary functions of grates are:

- Support the burning refuse
- Move and agitate the burning refuse
- Distribute the primary air.

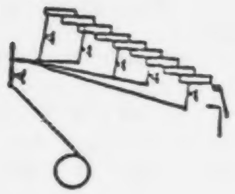
There is a wide range of differing design philosophies aimed at achieving these three functions. While all the grates observed do accomplish these primary functions, they do so at varying levels of grate maintenance required and with varying success in achieving uniform combustion.

The grate burning capacities for the plants visited range from 24.6 down to 3.33 tonnes (27 to 3.7 tons) per hour, a unit size range of 7.4 to 1. And the burning rates range from 560 down to 175 kg/m2/hr (114.6 to 35.8 lb/ft2/hr), a range in rates of 3.2 to 1.

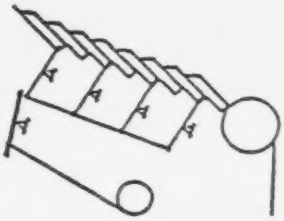
If all other factors are equal, the higher the grate burning rate, the more effective and efficient the grate will be. However, the effect of the grate on the combustion in the boiler furnace is of critical importance to boiler-furnace life and efficiency. It appears that one popular design philosophy is to use moderate burning rates and large boiler furnaces to provide reasonable heat recovery efficiency while minimizing maintenance. Another more bold approach is to design for much higher intensities of burning but to use precise control of primary and secondary air to assure relatively uniform, but intense combustion and rapid furnace-gas mixing. This involves the careful control of high-pressure primary and secondary air. In effect, this philosophy aims for accurate control of air-fuel ratio throughout the active burning areas of both grate and furnace. A critical factor in successful application of this intense burning mode is primary air pressure. To some extent, the successful pressure ranges used are considered proprietary by some manufacturers. The nominal design pressure of the primary air for each plant ranges from 140 to 580 mm water.

The highest primary air pressure shown is for Unit No. 3 at the Hagenholz plant at Zurich, started up in 1973. The detailed plant report indicates outstanding performance by this particular unit which probably can be ascribed, in part, to the excellent combustion control provided by the grate which utilizes a high primary air pressure. However, many other factors are also contributory.

Reciprocating Grate



Reverse Acting Grate



Roller Grate

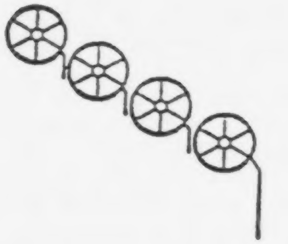


FIGURE A-13. BASIC TYPES OF GRATES FOR MASS BURNING OF REFUSE. THERE ARE AVAILABLE MANY VARIATIONS OF THESE BASIC TYPES (FROM EBERHARDT-PROCEEDINGS 1966 NATIONAL INCINERATOR CONFERENCE, ASME, NEW YORK, p 124-143)

TABLE . REFUSE BURNING MANUFACTURERS AND REPRESENTATIVES
(Grate and Suspension Firing)

International Technology	Country	Representative in the U.S.A.
Alberti-Fonsar	Italy (Milan)	Widmer & Ernst (Swiss Co.)
Babcock Wilcox (BW)	U.S.A. (North Canton, Ohio)	Babcock Wilcox
Bruun & Sorensen	Denmark (Aarhus)	looking for repre.
Carbonisation Enterprise et Ceramique (CEC)	France	
Claudius Peters	West Germany (Hamburg)	
Combustion Engineering (CE)	U.S.A. (Windsor, Conn.)	Combustion Engineering
De Bartolomeus	Italy (Milan)	
Destructor	Sweden	
Detroit Stoker	U.S.A. (Monroe, Mich.)	Detroit Stoker
Dominion Bridge	Canada	
Esslingen	West Germany	
Flynn & Emrich	U.S.A. (Baltimore, Md.)	Flynn & Emrich
Foster Wheeler	U.S.A. (Livingston, N.J.)	Foster Wheeler
Heenan	United Kingdom	
International Incinerators	U.S.A. (Columbus, GA.)	International Incinerators*
K K K		
Kunstler Koch	Switzerland (Zurich)	Widmer & Ernst
Keller-Peukert	West Germany (Leverkeusen)	Grumman Ecosystems
Kochum-Landsverk	West Germany	
Kohlenscheidungs-Gesellschaft (KSG)	West Germany	
Kraus-Maffei	West Germany	
Lambian-SHG	West Germany (Kassel Bettenhausen)	
Lokomo	Finland	
Lurgi	West Germany (Frankfort)	
Martin	West Germany (Munich)	Universal Oil Products
Nichols	U.S.A.	Nichols Research & Engineering
Plibrico	U.S.A. (Worcester, Mass.)	Plibrico
Riley Stoker	U.S.A. (Chicago, Il.)	Riley Stoker
Stein	France	
Steinmueller	West Germany (Hamburg)	Widmer & Ernst (Swiss Co.)
Takuma	Japan (Osaka)	Inactive representative in CA.
Venien	France	
Vereinigte Kesselwerke (VKW)	West Germany (Duesseldorf)	Grumman Ecosystems (total system)
Volund	Denmark (Copenhagen)	Waste Management Inc.
Von Roll	Switzerland (Zurich)	Wheelabrator - Frye
Widmer & Ernst	Switzerland (Wettingen)	Widmer & Ernst
Zurn Industries	U.S.A. (Erie, Pa.)	Zurn Industries

NOTE:
1. The above systems are combuston oriented.
2. Small modular package incinerator - heat exchanger manufacturers are not included.
3. Pyrolysis and other developmental resource recovery systems are not included.
4. The above systems have been installed with energy recovery.

Ash Handling and Recovery

For purposes of this discussion and design of refuse energy plants, there are five kinds of ash, residue or slag that need to be defined:

- Ash, Residue, Slag are general terms loosely used to name the solid waste product after combustion. This is also referred to as residue in America and slag in Europe. It may contain bottom ash, grate siftings and or flyash
- Bottom Ash is the solid residue falling off the grate end and into the chute
- Grate Siftings are the relatively small particles and dust falling under the grate normally through the spaces where the primary underfire air rises
- Fly Ash is the fine solid waste material that falls from boiler tubes and electrostatic precipitator plates either naturally or when blown off by soot blowers or when mechanically rapped
- Processed Ash is the sorted nonferrous aggregate of stone, dirt, glass, etc. usually less that 1.5 cm (0.6 inch) ready for use as road aggregate or cinder block, etc.

Table A-26 summarizes ash handling and recovery options exercised at the 15 visited plants. Generally speaking ash handling is somewhat more advanced in Europe over the U.S.A. Ash recovery is practiced much more in Europe than in this country. Of the 15 plants, 9 have ash recovery.

Ash Exit from Grate, Quenching and Removal from the Furnace

All systems arrange for the moving grate to discharge the hot, unburned residue into a water sump, quench tank or a spray chamber from which it is removed by a variety of methods. The residue, usually containing less than 3 percent combustible, is a highly variable material both in size and composition. Quenching is necessary because if the glowing residue were removed from the plant in its high temperature condition the dust and odors emitted from the hot surface would frequently be a nuisance.

Usually the residue is continuously removed from the tank. During that movement it is partially dewatered or drained by a drag conveyor or some form of hydraulically-driven ram or pusher. The wet residue then is discharged to a holding pit or movable bins. Trucks then transport the ash to a processing plant or to a landfill.

The quench container is the sink for the boiler blowdown water and other dirty water at most plants. Often this result in no wastewater (except for sanitary waste water) leaving the plant (except in ash trucks). If scrubbers are not used, zero wastewater discharge can be a reasonable challenge for designers. This is the reason that this report does not have a chapter devoted to water pollution control --- in most systems there is no real water pollution.

TABLE A-26. SUMMARY OF ASH HANDLING AND RECOVERY METHODS

	Werdenberg-Liechtenstein	Baden-Brugg	Duesseldorf	Wuppertal	Krefeld	Paris:Issy	Hamburg:Stellinger-Moor	Zurich:Hagenholz	The Hague	Dieppe (and Bonneville)	Gothenburg	Uppsala	Horsens	Copenhagen:Amager	Copenhagen:West	TOTAL
In Plant Ash Handling*																
• Reciprocating Push Room						X	X	X					X			
• Vibrating Conveyor						X	X	X				X				
• Steel Slat Conveyor				X	X				X							
• Rubber Conveyor	X	X	X			X		X	X	X	X			X		
• Skip Hoist													X		X	
• Detachable Container	X	X				X				X		X	X			
• Ash Pit				X	X											
• Ash Floor with Wheeled Front End Loader	X															
Quench Method*																
• Bottom of Chute Has Water						X	X	X			X					
• Water Pit									X							
• Trough	X			X					X							
• Ash Bunker is Wet				X							X					
Ash Recovery																
• Enclosed Building Recovery			X			X										2
• Outdoor Recovery				X			X	X	X					X	X	6
• Distant Recovery					X											1
• No Recovery at Plant	X	X								X	X	X	X			6
Recovery Operation Ownership																
• Plant Itself			X			X								X	X	
• Private Contractor, Receiver and Processor				X	X		X	X	X							
Separable Ash Components*																
• Ferrous Fines (caps, lids, nails)				X				X							X	
• Ferrous Coarse (cans)				X				X							X	
• Ferrous All Sizes						X	X		X					X		
• Ferrous Bulky (bicycles, barrels)				X			X	X	X						X	
• Ferrous Baled			X													
• Road Aggregate			X	X		X	X	X	X						X	
• Bulky Non Ferrous (stumps, tires, paper rolls)				X			X	X	X						X	
• Medium and Coarse Non Ferrous (2" stones, bones)			X	X												
• Land Reclamation Material					X		X							X		

* The X pattern is not complete or definite.

Ram for Residue Removal

The simplest and most compact reside removal system uses a curved-bottom tank which is cleared by a slowly reciprocating pusher. As the submerged residue is pushed upward toward the left by the ram it has time to drain off excess water before it drops into the pit, buggy, truck or other container. The discharge channel is tapered outward in the direction of motion to prevent packing and jamming.

Submerged Conveyor

Another common type of submerged drag conveyor which slowly lifts the residue upward along a sloping channel so that it has time to drain.

The conveyor housing is often reinforced concrete to resist the corrosive attack of the acids which accumulate in the quench water.

Spray Quench with Conveyor

An alternate system which avoids some corrosion problems of the quench tank is the use of a water spray to quench the residue as it falls off the end of the grate. The moisture pickup of the residue is much less with this system although it is more difficult to cool large, red hot clinkers than by submersion. From the spray quench the cooled residue falls into a belt or trough conveyor.

Furnace Wall

Most of the plants that were visited utilized water-tube cooling of the furnace wall. This type of wall has been translated from coal-burning to refuse-burning practice over the period since about 1960. In some cases the furnace is only partially water-cooled with the rest of the wall formed of conventional refractory. In all cases where wall tubes are used these tubes are a part of the boiler flow system. They are pressurized to boiler pressure and they supply a mixture of heated water and saturated steam to the boiler steam drum. Thus from a flow standpoint they are considered an integral part of the boiler system.

However, from the standpoint of combustion, the wall tubes are an essential part of the heat recovery from the flame that helps to cool the gases to a temperature level that is safe for them to pass on to the superheater and boiler convection banks. Thus the water-tube walls of the overall boiler system are treated here as a separate component of the combustion system while recognizing that they also constitute an important element of the overall boiler.

Furnace Requirements

The complex variety of furnaces now in use has evolved because of the interaction of several different requirements:

- Temperature: High pressure for steam power generation versus low-pressure steam or hot water for heating only. Low-pressure boilers are much cheaper to build, operate, and maintain.
- Size: Small furnaces need not be water-cooled if waste burning rates are moderate because the high surface-to-volume ratio of the small chamber facilitates cooling. Large furnaces are more likely to need water cooling because the wall surface is relatively small in proportion to the volume; hence, normal heat loss through refractory walls becomes insufficient to keep the refractory cool enough to survive.
- Fly Ash: The highly variable but active chemical nature of the fine ash produced, which can foul and corrode water-tube walls and boiler surfaces.
- Refuse Heat Valve: The remarkable increase in heat value of European municipal refuse since World War II, which has markedly changed furnace wall design requirements.

Residential heating was converted from coal to oil which produced no ash residue. Paper and plastic packaging of consumer products became widespread.

In a 1965 article, Mr. R. Tanner, father of the modern water-tube wall refuse furnace, stated the following:

> "For, as the calorific value rises, the uncooled combustion chamber leads to chamber temperatures that can no longer be controlled by air injection and fume feedback (flue-gas recirculation) alone. Thus, the adoption of radiation heating surfaces is becoming essential for refuse firing systems as it has long been usual in firing systems involving higher grade fuels."*

In this latter phrase, Tanner was referring to the fact that coal- and oil-fired furnaces, once refractory walled, had by the late 1940's, been largely changed to water-tube wall construction.

A significant goal of heat recovery in these waste-to-energy plants is to cool the exhaust gases to a temperature level of 117 to 260 C (350 to 500 F) where reasonably sized, high efficiency electrostatic precipitators will be practical. However, up until the early 1960's, there was considerable reluctance to locate the waste heat boiler surfaces too closely with the furnace. In 1969, Hotti and Tanner stated that a common earlier attitude was: "The combustion chamber must not be cooled. Designers thought that cooling would not permit reaching an adequately high combustion temperature". However, as the heat value rose, for example, in Berne, the average heat content rose from 1,160 Kcal/Kg (1,090 Btu/lb) in 1955 to 1,950 Kcal/Kg (3,510 Btu/lb) in 1964, rising furnace temperatures probably caused increasing troubles with refractory maintenance. Accordingly, Hotti and Tanner observed in 1969: "The trend of boiler development steered mainly toward adjustable radiation heating surfaces in the combustion chamber..." These same authors, Hotti and Tanner*, then pointed out that at their next plant at Ludwigshafen in 1967, "...the radiation surfaces surrounding the combustion chamber can be studded and covered with rammed material or, alternatively, stripped bare, as required". An earlier plant at Helsinki in 1961 had also used

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* Tanner, R., "The Development of the Von Roll Refuse Incineration System," Sonderdruck aus Schweizerischen Bauzeitung, 83, Jahrgang, Heft 16, (1965).

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* Hotti, G. and Tanner, R., "How European Engineers Design Incinerators," American City, June 1969.

water-tube-walls. Thus, with this company, the transfer of water-tube-wall technology from well-developed coal-burning practices to waste-to-energy plants occurred in the mid-1960's.

Meanwhile, the first large water-tube-wall boiler, 264 tons/day, had been installed at Essen-Karnap in 1960 as part of an existing coal-fired power plant.* Pulverized coal was fired above the refuse fuel bed.

During the same period, the Martin grate, originally applied to the burning of brown coal, was adapted at Munich to water-tube-walled furnaces for the large-scale burning of municipal refuse for power generation. Bachl and Mykranz* described the first Munich unit in an extensive article published in Energie, in August, 1965. Pulverized coal was fired in a separate furnace. In a second unit, the coal was fired directly above the refuse.

Secondary (Overfire Air)

All grate-burning of fossil fuels requires overfire air jets above the fuel bed for smokeless, complete combustion.

Mass burning of refuse has very similar requirements. In addition, at very high refuse burning rates in large furnaces, the turbulent mixing provided by jets is of critical importance in assuring complete combustion of the furnace gases before they reach the superheater. If this combustion is not completed well ahead of the superheater, the ash deposits on the tubes can become overheated by the hot, burning gases and tube corrosion can occur as discussed under Metal Wastage.

As with fossil-fuel practice the application of overfire air jets for mass burning of refuse is still an art and from plant to plant the details of application vary considerably. Some vendors are much more committed to the application of highly intense overfire turbulence than are others.

Principles of Overfire Jets

To abate smoke formation the unburned volatile gases rising from the fuel bed must be mixed rapidly with ample oxygen. If this mixing does not occur promptly the rich gases are very likely to decompose thermally because of the high temperature, thereby releasing fine carbon particles that form smoke and soot.

Because of the principle of prompt and early mixing just described the jets should be relatively near to the fuel bed. But because of the construction of some furnaces this is very difficult to arrange from either the front or rear walls. Accordingly some furnaces are equipped with sidewalls jets so that the jets can be located low in the furnace on a line parallel to the sloping fuel bed. If such sidewall jets are suitably spaced and staggered so that the opposing jets intermingle , mixing can be very effective. However, if the jets are directly opposite each other and are too closely spaced, they have a tendency to drive the flame toward the center of the furnace where oxygen may be deficient. Such an arrangement, then, can cause a longer flame to rise out of the furnace center. A few plants then use tertiary jets located higher up in the furnace wall to make sure that rising tongues of flaming unburned gases are quickly mixed with ample oxygen.

Because of the inherent limitations of sidewall jets just described, many designers prefer front-wall and rear-wall or similarly situated jets, because the main gas flow can often be mixed by such jets without displacing the flame toward the center of the furnace.

In all cases, whether sidewall, front-wall or rear-wall care must be taken to avoid too intense burning in the immediate area around the jet opening. As the jet of air emerges into the chamber at high velocity, 50 to 100 m/s (164 to 328 f/s), it induces rapid inward flow of furnace gases along the wall toward the jet. If this rapid influx occurs in a region of active burning the turbulent flow induced by the jet can cause intense local burning and very high temperatures that can deteriorate either refractory or water-tube walls and can aggravate slagging. If this phenomenon is observed, the solution is to reduce the secondary air jet pressure on the few jets involved to a level where the induction effect is minimal.

If such reduced jet velocity then impairs the desired mixing effect in the main part of the furnace, tertiary jets should be considered.

Usually the quantity of overfire air supplied ranges from 10 to 25 percent of the total combustion air, primary plus secondary. Since most furnaces already have ample excess air, the main objective of overfire air jets is to provide good mixing and not to add air. Thus additional air is usually less important than turbulence for intense mixing. Thus small jets introducing very high velocity air are usually preferable because this minimizes the amount of air added.

Table A-27 shows the range of jet conditions employed in the plants visited. Volume III points out the features of each installation and the drastic changes that have been made at a few plants to improve jet performance. The art is still evolving.

Boilers

In this research on Refuse-fired Steam-and Hot Water-Generators the most important single component of the plant and often the most costly, is the boiler. However, the word "boiler" may not convey the same meaning to all engineers.

In this report, boiler is defined to mean a closed pressure vessel, a set of interconnected tubes and drums acting as a fluid system containing water or steam or a mixture of the two at essentially a constant pressure throughout that has a function of producing superheated water, saturated steam, or superheated steam.

Overall Boiler Design

It has taken a long time for some waste-to-energy plant designers to become fully aware that refuse is not coal. Refuse is:

- More variable
- Less dense, but subject to amazing variation in density, especially if very wet
- High in chlorine

TABLE A-27. SECONDARY AIR SYSTEMS

	Date Started	Rated Furnace Tonnes/Hour	Original Overfire Jets: Number of Jets			Size, Dia.		Available Air Volume		Max. Available Pressure		Proportion of Total Air	Overfire Air M^3/mton Capacity	Jet Revisions or Details	
			Front	Rear	Sides	mm	in	Nm^3/h	Scfm	MmH_2O	in H_2O	Per-cent		Date of Revision	Type of Revision
Wardenberg	1974	5	--	--	18 ea	60	2.36	30,500	17,934	385	15	---	6100	---	2 Levels jets on each side
Baden-Brugg	1970	4.2	--	--	18 ea			15,000	8,820	---	--	---	3570	1974	15-64mm(25in) jets in front and rear; pressure front 500mm (19.7 in) rear 400mm (15.7 in)
Duesseldorf	1965	10	18	20	6 ea			4,000	2,354	280	11	---	400	1967	Secondary air vol. increased to 10,172 Nm^3/hr.
	1972	12.5	18	20	18 ea			15,000	8,828	800	31.5	---	1200	196-	Some jets converted to recirculate flue gas but this was discontinued
Wuppertal	1976	15	30	30	---	50	2	20,000	11,650	800	31.5	---	1333		Actual volume of overfire air used is 60 to 70% installed of capacity
Krefeld	1976				---	—	--			---	---	---		---	
Paris-Issy	1965	17	4	32	---	--	--	72,000	42,336	400	16	20-25	4235	---	The maximum jet pressure is estimated
Zurich:Hagerholz	1973	21	22	22	---	—	--	16,000	9,408	730	29	20	762		No sidewall jets are used because of tendency to push flame toward center
Hamburg:S.-Moor	1972	24	16	16	---	--	--	17,500	10,290	640	25	---	729		
The Hague	1968	15	0	0	0	--	--	0	0	---	--	0	0	1969	9 Sidewall jets 50mm dia were added on each sidewall, 21,000 Nm^3/hr, giving 1400m^3/tonne of capacity
Dieppe	1974	2.5	0	0	0	—	--	0	0	---	--	---	0	1974	Front wall jets were added at Dieppe, 5000Nm^3/hr, giving 2000m^3/tonne of capacity
Gothenberg	1970	15	0	0	18 ea	--	--	33,000	19,420	280	11	---	2200	1976	Sidewall jets replaced by 9, 8mm dia jets in back, 7 in front. Three of the front jets are 150mm dia.
Uppsala	1970	5	--	--	---	--	--	--	--	---	--	---		--	Some primary air is used as secondary dilutive air
Horsens	1974	5	0	--	0	--	--	--	--	250	10	10	--	--	
Amager-West	1970	12	0	0	8 ea	--	--	35,000	20,580	460	18	--	2917		Flue gas can also be recirculated for furnace tempering.

- Always changing
- Usually has much higher alkali content in the ash
- Feeds poorly
- Can lose ignition if wet or can almost explode with threatening intensity.

Boilers and stokers, following well established design, have not always been designed to cope with these properties. Accordingly, refractories, tube walls, and superheaters have suffered.

Some designers still don't seem to be enough aware of these effects.

On the other hand, in about 1965 or 1967, someone in Martin and Von Roll evidently began to perceive that the superheater must not be located where, even momentarily, its ash deposits could become overheated. Thus, the Paris (Issy) (1965) and Ludwigshafen (1967) designs had the superheater after a second, open radiant, water-tubed pass.

But Martin didn't use this again until 1971 at Kezo-Hinwil and 1972 at Hagenholz. And VKW even hung the superheater in the first pass as recently as 1972 in Unit 5 at Dusseldorf. Then in 1976 at Krefeld and Wuppertal, VKW placed the superheater beyond the first pass. Now in 1976, Widmer & Ernst at Werdenberg has included the open second pass ahead of the superheater.

Oddly, when Von Roll built Saugus near Boston in 1975, they included no open second pass; but at Stapelfeld, to be completed in 1980, Widmer & Ernst will. So the choice between the lower cost, close-coupled boiler-superheater arrangement, and the more costly double-open pass is still not yet clear among the various designers.

There are good reasons for the differences in plant design that were encountered and there is much evidence of a continuing process of evolution. At this time, 1977-78, it appears that the current "best" boiler-furnace design in use for large, high-pressure units is the completely water-tube-walled furnace and radiant section, studded and coated with thin refractory in the intense burning zone, followed by one or more long, open, vertical radiation passes preceding a convection-type superheater and boiler-convection passes and an economizer.

However, an emerging newer philosophy is to follow the tall water-tube-walled chambers by a long horizontal superheater and convection section. This is called the "dacha" boiler because of its extended horizontal configuration. Figure A-14 shows such a design for the proposed Staplefeld plant at Hamburg. The purpose of this design is primarily to enable all of the boiler convection tubes and, in many cases, the superheater tubes as well, to be suspended vertically in the horizontal gas passage. This arrangement makes it relatively easy to remove and replace failed tubes from the top. It also facilitates the removal of ash deposits from those vertical tubes by means of mechanical rapping. Thus, the common threat of the erosive action of steam-jet soot blowers is eliminated. It is too early to tell how effective this cleaning method will be in the long run.

It is notable that the Stapelfeld (to begin operation about 1979) platen-type superheater is preceded by an open, water-tube-walled second pass to assure that the superheater is not touched by excessively hot flame or furnace gases. Furthermore, it is in a location such that it is completely shielded from furnace radiation. A similar design philosophy is apparent at the Werdenberg and Zurich plants. Both of these factors will combine to keep the ash deposits on the superheater from becoming heated to the point that chlorine may attack the metal.

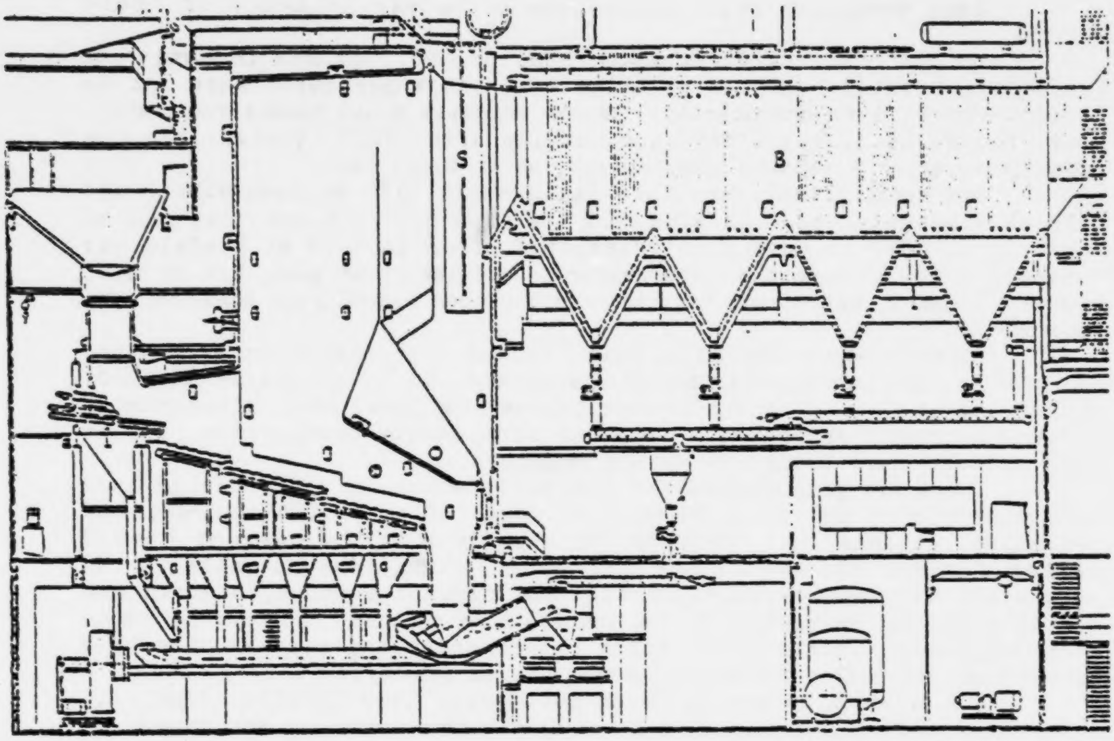

FIGURE A-14. DACHA TYPE SUPERHEATER AND BOILER CONVECTION ARRANGEMENT FOR PROPOSED STAPELFELD PLANT AT HAMBURG (COURTESY WIDMER & ERNST). S - Superheater
B - Boiler Convection Section

Tube and Wall-Cleaning Methods

In conventional boiler practice, the accepted method for removing ash and carbon deposits periodically from the heating surfaces is by means of steam-driven jets or "soot-blowers." However in refuse-burning practice most plant operators have quickly learned that the high-velocity jets of water slugs and steam from steam soot blowers can accelerate corrosion by removing too much of the ash deposit. As discussed under metal wastage, the ash deposit serves as a protective layer and corrosion inhibitor. When the bare tube metal is exposed once or twice a day by excessive soot blowing, high temperature chloride corrosion can be very rapid.

Accordingly some plants have abandoned soot-blowing completely. Many have learned to use the soot blowers sparingly and then only in those locations where occasional surface cleaning is particularly important to satisfactory operation. Some have turned to compressed air blowers to avoid any possibility of having slugs of steam-condensate being blasted against the tubes during soot blowing. Others have arranged the convection surfaces so that they can be shot-cleaned by a periodic or continuous cascade of steel or aluminum falling shot. Others use mechanical rapping of vertically suspended tube banks.

Tables A-28 and A-29 list the various furnace-boiler cleaning techniques employed at the plants visited.

Steam Condensers

At times when the connected energy demand is low, some quantities of steam must be condensed in either water-cooled or air-cooled condensers. This is done at 6 of 15 plants as listed below:

TABLE-B-3. DATA REGARDING CLEANING OF HEAT-TRANSFER SURFACES IN VISITED REFUSE-FIRED STEAM AND HOT-WATER GENERATORS

Plant	Original Cleaning Method				Supplemental Methods		Revised Cleaning Methods				Washing		Tube Protection Opposite Soot Blowers	Comments
	Soot Blowers	Blowing Frequency	Steam bar	Pressure psig			Number of Soot Blowers	Blowing Frequency	Steam bar	Pressure psig	Type	Frequency		
Werdenberg	None	-	-	-	Shot	4min/hr	None	None	-	-	None	-	None	Mfg. favors rapping
Baden-Brugg	Steam	None	-	-	Hand	Every 6 weeks	None	None	-	-	None	-	None	Soot blowers not used because of danger to tubes
Duesseldorf	Steam	-	-	-		-	-	-	-	-	High Pr. water	2000 hrs, #1-4 5000 hrs, #5	Alloy Steel	Soot blower caused wastage only in economizer
Wuppertal	Steam	-	15	215	-	-	-	-	10	60	Discontinued		4mm Sicromal	Water threatened refractories
Krefeld	Only 1 steam blower	-	-	-	-	-	-	-	-	-	None	-	None	Co-firing system
Paris:Issy-les-M.	Steam	-	-	-	Steel shot in economizer	-	Discontinued, suphtr. cleaned manually				None	-	None	-
Zurich:Hagenholz	Air	-	Air 15	240	Steel shot in economizer	-	-	-	-	-	Alkali	4000 hrs	None	Experimenting with suphtr. vibrator
Hamburg:S.-Moor	Steam	1/shift	18	260	-	-	-	1/3rd shift	14-16	200-230	None	-	Sicromal 10	-
The Hague	Steam	1/shift	20	290	-	-	Discontinued		-	-	Alkali	Every 3 mo.	None	Could go 8,000 hr between washings
Dieppe-Deauville	None	-	-	-	Dieppe-manual brush Deauville-steel shot	- -	2-3 kg Additive every 2-3 hours				None	-	-	Firetube boilers Deauville uses additive
Gothenburg	11 steam blowers	1/shift	22	313	-	-	16	Less Frequently	22	313	None	-	Alloy Steel angles	Shields need replacement every 6 mos.
Uppsala	None	-	-	-	Shot, Aluminum	Continuous	-	-	-	-	None	-	-	-
Horsens	None	-	-	-	Powered Rotary Brush	Every 2 weeks	-	-	-	-	None	-	-	Firetube boiler
Copenhagen:Am-W.	Steam	-	-	-	Shot	-	Tried Sonic Vibration, rapping				None	-	-	3 passes brushed manually

TABLE A-29. METHODS USED TO CLEAN TUBES AND WALLS OF EUROPEAN REFUSE-FIRED ENERGY PLANTS.

A. Automatic Remote Controlled Soot Blowing

1. Fixed Position - rotary motion
2. Retractable Positions - spiraling motion
3. Steam
4. Compressed air

B. Mechanical Rapping

1. Automatic continuously operating hammers
2. Sledge hammering of boiler tube bundles by operator
3. Unbalanced compressed air vibrator

C. Automatic Shot Cleaning

1. Falling aluminum shot
2. Falling steel shot

D. Chemical Additive

1. Blowing inorganic "Gamlenite 8" dust to soften deposits

E. Non-Chemical and Manual Cleaning of Cooled Furnace

1. Compressed air manually operated nozzles
2. Small miscellaneous brushes
3. Manual scraping
4. Pneumatic hammering
5. Powered rotating wire brush for fire-tube boiler

F. Chemical and Manual Cleaning of Cooled Furnace

1. Soak with alkali, sodium carbonate or other chemicals
2. Rinse with high pressure water jets
3. Soak again
4. Rinse again
5. Scrub with brushes, pneumatic hammers and other tools
6. Sand blast difficult deposits.

Boiler/furnace design conditions are shown in Table A-30. Boiler heat release rates are shown in Table A-32. Comparative energy recovery figures for Harrisburg, PA.; Gothenburg, Sweden; Zurich, Switzerland and Duesseldorf, Germany are shown in Table A-31.

Steam Condensers

At times when the connected energy demand is low, some quantities of steam must be condensed in either water-cooled or air-cooled condensers. This is done at 6 of 15 plants as listed below:

Plant	Mode of Cooling Steam
Werdenberg	Air
Baden-Brugg	Water
Wuppertal	Air
Hamburg:Stellinger-Moor	Air
Zurich:Hagenholz	Air
Gothenburg:Savenas	Air

Supplementary Firing of Fuel Oil, Waste Oil and Solvents

Number 2 Fuel Oil can be fired at five of the surveyed plants. Waste oil and/or solvents are fired at three plants, as shown in Table A-33.

The reasons for supplementary firing are:

- Emergency standby backup
- Routine firing when refuse burning ceases on weekends
- Preheat the RFES upon startup
- Keep boiler and electrostatic precipitator "hot" to prevent dew point corrosion when unit is down
- Supplemental fuel oil keeps furnace temperature at legal limit for destruction of pathogens, etc.
- Additional energy for routine uses.

In designing a total system, it is important to also consider the various reasons for not spending funds to install such supplemental firing features.

In each case listed below, the facility provides base load interruptable energy. Often, if the refuse to energy plant does not have continuous responsibility (as in the interruptable situation) the revenue per 1000 pounds of steam is less.

The reasons for no supplementary firing are:

- Hot water to a district heating system where the system has other oil fired district heating stations
- Industrial process steam to a user that maintains his own older conventional boiler ready for startup should there be an interruption in the supply of refuse derived steam
- Electricity to an electric network where the loss of refuse derived electricity would have ltitle effect on total network operations
- Drying and burning of sewage that can be postponed several hours or days if the sludge storage tanks are large enough

TABLE A-30. BOILER FURNACE DESIGN CONDITIONS

Trip		No. of Boilers	Year Started	Rated Refuse Input		Maximum Refuse Input		Design Lower Heat Valve			Steam (or Water) Temperature	
				mt/h	t/h	mt/h	t/h	Kcal/Kg	KJ/Kg	Btu/lb	C	F
1	Werdenberg-Liechtenstein	1	1974	5.0	5.5			2800	11,724	5040	395	740
2	Baden-Brugg	2	1970	3.33	3.66	5.0	5.5	2600	10,886	4680	400	752
3	Duesseldorf Boilers 1-4	4	1965	10.0	11.0			1850	7,746	3330	500	932
	Boiler 5	1	1972	12.5	13.8			2110	8,835	3800		
4	Wuppertal	4	1976	15.0	16.5			2250	9,421	4050	350	662
5	Krefeld	2	1976	12.0	13.2			2250	9,421	4050	376	700
6	Paris:Issy	4	1965	17.0	18.7	19.9	21.9	1800	7,537	3240	410	770
7	Hamburg:Stellinger-Moor	2	1972	18.8	20.6			1800	7,537	3240	410	770
				24.6	27.1			1500	6,281	2700		
8	Zurich:Hagenholz	(1)	1973	21.0	23.1			2300	9,630	4140	420	788
9	The Hague Boilers 1-3	4	1965	15.0	16.5			1800	7,537	3240	425	797
	Boiler 4		1974	15.0	16.5			2300	9,630	4140		
10	Dieppe (and Deauville)	2	1971(76)	2.8	3.1			2000	8,374	3600	180	365
11	Gothenberg	3	1970	12.5	13.8	15.0	16.5	2500	10,468	4500	217	423
12	Uppsala	(1)	1970	5.0	5.5			2450	10,258	4410	138	389
13	Horsens	1	1974	5.0	5.5			2800	11,724	5040	110	230 (water)
14	Copenhagen:Amager	3	1970	12.0	13.2	13.0	14.3	2000	8,374	3600	120	248 (water)
15	Copenhagen:West	4	1970	12.0	13.2	13.0	14.3	2000	8,374	3600	170	338 (water)

(1) There are older boilers in this plant. Only the newest one is considered in this report.

(2) Part of the burning occurs in a cyclonic after-combustion chamber.

TABLE A-31. BOILER RELEASE RATES

		No. of Boilers	Total Design Heat Release per Unit			Combustion Volume		Design Volume Heat Release Rate		
Trip			Gcal/h	GJ/h	MBtu/h	m^3	ft^3	$Kcal/m^3$-h	KJ/m^3-h	Btu/ft^3-h
1	Werdenberg-Liechtenstein	1	14.00	58.5	55.4	142	5012	98,591	412,800	11,060
2	Baden-Brugg	2	8.65	36.2	34.3	66	2330	131,060	548,722	14,700
3	Duesseldorft Boilers 1-4 Boiler 5	4 1	18.50 26.37	77.5 110.5	73.3 104.7	178 268	6285 9458	104,000 98,470	435,000 412,300	11,650 11,066
4	Wuppertal	4	33.75	141.3	133.7	164	5826	204,500	856,000	22,990
5	Krefeld	2	27.00	113.1	106.9	171	6038	157,895	661,000	17,747
6	Paris:Issy	4	30.60	128.1	121.2	163	5753	187,526	785,170	21,034
7	Hamburg:Stellinger-Moor	2	33.84 36.90	141.7 154.5	134.0 146.1	165	5823	205,090 223,636	858,710 936,320	22,857 25,058
8	Zurich:Hagenholz	(1)	48.30	202.2	191.2	284	10023	170,070	712,050	19,000
9	The Hague Boilers 1-3 Boiler 4	4	27.00 34.50	113.1 144.5	106.9 136.6	232 258	8188 9110	116,379 133,721	487,250 560,000	13,052 14,997
10	Dieppe (and Beauville)	2	5.60	23.4	22.2	80	2823	70,000	293,090	7,905
11	Gothenberg	3	31.25	130.8	123.8	263	9281	118,821	497,480	13,325
12	Uppsala	(1)	12.25	51.3	48.5	50	1765	245,000	1,025,000	27,494 (2)
13	Horsens	1	14.00	58.5	55.4	62	2188	225,806	945,400	25,338 (2)
14	Copenhagen:Amager	3	24.0	100.5	95.0					
15	Copenhagen:West	4	24.0	100.5	95.0					

(1) There are older boilers in this plant. Only the newest one is considered in this report.

(2) Part of the burning occurs in a cyclonic after-combustion chamber.

TABLE A-32. COMPARISON OF ENERGY RECOVERY

	Pressure		Temp.		Enthalpy of Steam Above 100F(37.8C)			Nominal Heat Value of Refuse (LHV)			Basis For Heat Value	Measured Evaporation Rate Steam/Refuse	Basis For Evap. Rate	Energy Production Rate Per Unit of Refuse			Efficiency Corresponding To The Indicated Value of Refuse %	Meas. Eff. %
	atm	psia	C	F	KJ/Kg	KCAL/Kg	BTU/lb	KJ/Kg	KCAL/Kg	BTU/lb				KJ/Kg	KCAL/Kg	BTU/lb		
Harrisburg (PA.,U.S.A.)	13	270	289	480	2905	694	1249	8094	1933	3480(1)	Anal.	2.56	Test (73)	7436	1776	3197	92	73
								8654	2067	3720	Anal.	3.09	Test (73)	8976	2144	3859	(?103)	82
								14049	3356	6040	Anal.	4.06	Test (73)	11795	2817	5071	84	66
								(41412)	(9891)	(17804)	(Oil)	(13.07)	Test (73)	-	-	(16324)	(92)	86
Gothenberg (Sweden)	25	367	224 (Sat)	436	2642	631	1136	9839	2350	4230	Estim.	3.09	'74 Yr.Avg.	8164	1950	3510	83	-
												3.13	'75 Yr.Avg.	8273	1976	3556	84	-
												3.18	'76 Yr.Avg.	8403	2007	3612	85	-
Hagenholz (Zurich)	37	544	420	788	3110	743	1337	9630	2300	4140	Estim.	2.58	'74 Yr.Avg.	8022	1916	3449	83	-
												2.41	'76 Yr.Avg.	7494	1790	3222	77	-
Dusseldorf (West Germany)	80	1176	500	932	3398	812	1461	7063	1687	3036	Anal.	1.77(2)	'73 Yr.Avg.	6016	1437	2586	85	-
								6640	1586	2855	Anal.	1.65	'74 Yr.Avg.	5606	1339	2411	84	-
								7310	1746	3143	Anal.	1.88	'75 Yr.Avg.	6389	1526	2747	87	-
								7603	1816	3269	Anal.	2.00	'76 Yr.Avg.	6795	1623	2922	89	-

(1) The Harrisburg lower heat values have been estimated by subtracting 7% from the measured higher heat values. Source: Battelle Performance Measurements.

(2) The Dusseldorf production was actually about 5% higher than shown because internally used steam does not appear here.

TABLE A-33. USE OF SUPPLEMENTARY FUELS AT 16 EUROPEAN REFUSE FIRED ENERGY PLANTS

	Supplemental Fuel	Remarks
Werdenberg-Liechtenstein	No. 2 Fuel Oil	Standby Package Boiler Operates Unmanned on Weekends
Baden-Brugg	Waste Oil	Decanting Station Prior to Burning in Refuse Incinerator, Fired When Highest Electricity Revenue Rate
Duesseldorf	No.2 Fuel Oil	Used on Startup and Emergency
Wuppertal	None	No Need - Electricity Produced is Accepted Into Network Grid intermittently
Krefeld	Waste Oil	Burning No Longer Permitted. Waste Oil Diverted to Regional Treatment Plant
Paris: Issy	None	No need - Energy from Plant is fed into the large district heating and electricity networks
Hamburg:Stellinger-Moor	No.2 Fuel Oil	Used on Startup. Burning of Methane Gas from the Sewage Treatment Plant has been discontinued.
Zurich:Hagenholz	No.2 Fuel Oil, Waste Oil, Solvents	Separate boiler. for virgin No. 2 Fuel Oil. Separate boiler for decanted waste oil and solvents. Common steam header for all three boiler systems.
The Hague	None	No Need. Steam is intermittently fed to adjoining electricity power plant
Dieppe (and Deauville).	None	No Need. Drying and Burning sewage sludge can be delayed.
Gothenburg	None	No Need. Refuse Energy plant is only one module of largest district heating system in world.
Uppsala	None	No Need. Steam is intermittently fed to adjoining oil fired district heating plant.
Horsens	None	No Need. Sludge drying can be delayed. Refuse energy plant is only one module of district heating system.
Copenhagen:Amager	None	No Need. Steam is intermittently fed to adjoining oil fired, district heating plant. The predecessor 1931 plant at Gentotte co-fired with coal.
Copenhagen:West	None	No Need. Steam is intermittently fed to adjoining oil fired district heating plant.
Cologne (Hospital Waste)	No.2 Fuel Oil	The supplemental Fuel Oil keeps the furnace temperature at its legal limit necessary to destroy contaminated (non-tissue) hospital waste.

- Energy to a physically adjacent conventionally fired energy plant where the total standby responsibility rests with the neighboring plant
- A regional plan that mandates waste oil treatment and burning at a distant facility.

Only 5 of the 16 plants described were designed with key functions being served by fuel oil, waste oil or solvents.

Co-Disposal of Sewage Sludge and Refuse

In 1977, the Europeans were well advanced over North Americans in the combined destruction of refuse and sewage sludge within the same system. Seven (7) such plants were visited in Europe. Several other plants are identified as well. Of note is that each of the six major European manufacturers visited during this project have a co-disposal system in operation.

Most processes involve several stages of drying as listed in Table A-34.a. Typically, a unit operation will convert incoming raw sewage sludge at 94-96 percent moisture to a 70-80 percent moisture. At this moisture level, the sludge has a thick consistency that can lead to dramatic further moisture reductions down to 5-20 percent. The third stage of several processes is to combust where, by definition, the moisture content of the sludge goes to zero. Thirty four (34) such systems are listed in Table A-34b.

From a reliability standpoint, each of the described processes does work a respectable part of the time. Unfortunately, economic data was not available for enough systems to perform any kind of economic analysis.

Air Pollution Control Equipment

Particulates

The emergence of the refuse-fired steam generator in Europe in the 1960's was a direct result of the growing desire for pollution control--especially control of flyash that made nuisances of many old incinerators. That is, the very dusty, hot gases from the incineration process had to be cooled before practical high efficiency flyash control could be applied. The most logical means for cooling that gas is by means of a boiler to produce useful hot water or steam. In some cases, usually small plants, where energy recovery was not attractive, the gas cooling has been achieved not through heat recovery but by means of water sprays or air-cooled heat exchangers. However this wasteful practice has not become widespread.

Regardless of the method used for cooling of the dusty flue gas, the almost universal method for particulate removal from the partly cooled gases has been electrostatic precipitation, (ESP). Here again the considerable experience already developed in coal-burning practice was available to guide the application of ESP's to RFES. One attempt was made to apply cloth filtration (baghouse) at Neuchatel but, although the system is still in operation, the results obtained were not outstanding.

Table A-35 shows the characteristics of the ESP's at the plants visited.

TABLE A-34a. CO-DISPOSAL UNIT OPERATION MOISTURE CONDITIONS

(Moisture of Sludge Alone or Refuse and Sludge (combined)

Unit Operation	Beginning Water %	Ending Water %
Band Press	94-96	70-80
Filter Press	94-96	45-50
Centrifuge	94-96	70-80
Mixing Sludge into Refuse Pit	94-96	20-30
Mixing Sludge into Dano Rotary Kilm for 2-3 days	94-96	?
Thin Film Dryer Using Steam from the RFSG	94-96	5-15
Rotary Kilm with Hot Flue Gas from Refuse Burning	94-96	40-50
Mixing Wet Sludge with Some 5-15% H_2O Dried Sludge	94-96	35-40
Hammermill with Hot Flue Gas from Refuse Burning	70-80	5-10
Making Bricolari Bricks Anaerobic Decomposition Over 1 Month Period	50-55	15-20
Breaking Up Bricks for Aerobic Decomposition	15-20	35-40
Aerobic Decomposition with Pipe Turning 2-3 times per wk.	?	35-40
Burning Refuse and Sludge on a Grate	25-40	0
Suspension Burning Above a Refuse Grate	5-15	0
Multiple Hearth Burning	?	0

TABLE A-34b. COMMERCIAL AND DEVELOPMENTAL SYSTEMS FOR CO-DISPOSAL OF REFUSE AND SEWAGE SLUDE LOCATION, MANUFACTURER, VOLUME, AND PROCESS

City	Country	Manufacturer	Lines	Rated Capacity Per Line M.T./Hour	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Process	Sewage Sludge M.T.Day Wet	Sewage Sludge M.T.Day Dry
Aarhus North*	Denmark	Bruun & Sorensen	2	8	192	384	1979	Flue gas to Rotary Drum		
Copenhagen:West*	Denmark	Volund	3	12	288	864	1970	Sludge is Dumped into Pit, Mixed with Refuse		
			1	14	336	336	1977			
						1,200				
Horsens*	Denmark	Bruun & Sorensen	1	6	144	144		Flue gas to Rotary Drum		
Arles	France	Martin	1	3.3	79	79	1974	?		
Brive	France	VonRoll	2	2.5	60	120	1977	Steam to Thin Film Drier		
Deauville*	France	VonRoll	2	2.5	60	120	1973	Steam to Thin Film Drier	30-40	
Denain	France	Martin	2	5.5	132	265	1976	?		
Dieppe*	France	VonRoll	2	2.5	60	120	1977	Steam to Thin Film Drier		
Bamberg	Germany	Keller Peukert(VKW)	2	6	144	288	1977	Flue Gas to Grinder, Drys Slude (?)		
Tengnier	France	Alberti-Fonsar	2	8	192	384	1971	Pilot Plant		
Fuerstenfeldbruck	Germany	Keller Peukert(VKW)	1	6	144	144	1975	Steam to Thin Film Dryer, Grinding Dryer (?)		
Geiselbullach	Germany	Keller-Peukert(VKW)	1	6	144	144		?		
Gluckstadt	Germany	Claudius Peters	1	2.5	60	60	1975	Closed		
Ingolstadt*	Germany	Widmer+Ernst	2	7.5	180	360	1963	Flue gas to Hammermill, Partial Recycle		
Krefeld*	Germany	VKW	2	12	288	576	1978	Flue gas to Hammermill, No recycle		
Dordrecht	Netherlands	Martin	3	7.7	185	595	1974	Flue gas to Multiple Hearth Furnace		
Lousta	Sweden	Bruun & Sorensen	2	9	216	432	1972	?		
Lulea	Sweden	Bruun & Sorensen	2	7.5	180	360	1968	?		
Bulach	Switzerland	Lurgi	2	2.25	54	108	1967	?		
Nieder-Uzwill	Switzerland	Nichols				88	1969	?	22-27	
Dubendorf	Switzerland	Nichols						RDF into Multiple Hearth Furnace. Closed in 1978.		
Reigate, England	U.K.	Lurgi						RDF into Multiple Hearth Furnace		
Alloa, Scotland	U.K.	Lurgi						RDF into Multiple Hearth Furnace		
Ansonia, Conn.	U.S.A.					55		Flue gas Dries, Sludge Used as Fertilizer		
Concord, Calif.	U.S.A.	Envirotech					1977	RDF into Multiple Hearth Furnace		
Glen Cove, N.Y.	U.S.A.							?		
Duluth, Minn.	U.S.A.						1979	RDF into Fluidized Bed	66	
Franklin, Ohio	U.S.A.	Black Clawson					1971	Hydropulped Residuals into Fluidized Bed		
Harrisburg, Penn.	U.S.A.	Martin					1972	Sludge is Dumped into Pit, Mixed with Refuse		
Hempstead, N.Y.	U.S.A.	Flynn & Emerick				600	1952	Steam first Drys Sewage Sludge		
Holyoke, Mass.	U.S.A.							Accepts 28% Solids Sludge. Dries Further. Suspension Fire.		
Norwalk, Conn.	U.S.A.							Sludge is Layered over Solid waste. Dries. Burns.		
Pompano Beach, Fla.	U.S.A.	Waste Management				100	1979	Anaerobic Digestion of RDF and Sludge		
Wilmington, Del.	U.S.A.	Raytheon				1,000	1982	Aerobic Digestion of RDF and Sludge		

*Cities that were visited by Battelle on this project.

TABLE A-35. CHARACTERISTICS OF ELECTROSTATIC PRECIPITATORS

	Year	Nominal Plant Capacity	Unit Capacity	Number of ESP	Gas Volume Per Unit		Design	Velocity	Number of Fields	Projected Collection Surface	
		tonnes per day	tonnes per hr		Nm^3/h $x10^{-3}$	scfm $x10^{-3}$	m/s	f/s		m^2	ft^2
Werdenberg	1974	120	5.0	1	83.0	48.8	0.67	2.2	1	1,142	12,288
Baden-Brugg	1970	200	3.3	2	64.0	37.7	0.70	2.3	1	952	10,247
Dusseldorf	1965	1,260	10.0	3	39.0	22.9	1.1	3.7	2	2,020	20,800
	1972		12.5	1			0.8	2.7	2	3,600	38,730
Wuppertal	1976	1,440	15.0	4	100.0	58.9	1.0	3.3	2	2,810	30,230
Krefeld	1976	576	12.0	2	86.0	50.6	1.0	3.3	2	2,810	30,230
Paris:Issy	1965	1,635	17.0	4	100.0	58.9	0.9	3.0	2	-	-
Hamburg:S-M	1972	1,180	18.8	2	90.6	-	1.15	3.8	2	-	-
Zurich:Hagenholz	1973	380(1)	21.0	1	95.6	-	0.81	2.7	2	3,560	38,306
The Hague	1965	1,440	15.0	4	90.0	52.9	2.0	6.5	2	-	-
Deauville(2)	1976	67	2.8	2	-	-	-	-	-	-	-
Gothenberg	1970	1,080	15.0	3	100.0	58.9	1.15	3.8	2	-	-
Uppsala	1970	120(1)	5.0	1	29.3	17.3	0.71	2.3	-	-	-
Horsens	1974	120	5.0	1	36.0	21.2	0.48	1.6	2	-	-
Copenhagen:Amager	1970	864	12.0	-	107.0	63.0	0.86	2.8	2	-	-
Copenhagen:West	1970	1,152	12.0	-	107.0	63.0	0.86	2.8	2	-	-

(1) Only the newest unit in this plant is considered here.

(2) Dieppe has centrifugal dust collection; Deauville has ESP, but for this small plant French regulations permit emission up to 600 mg/Nm^3 (0.26 gr/scf).

TABLE A-36. MEASURED GASEOUS EMISSION RATES AT EUROPEAN RFSC (Numbers in parenthesis indicate CO_2 level to which the concentration is adjusted)

PLANT	CO_2	HCl	HF	SO_2+SO_3	NO_x	OTHER
	%	mg/Nm^3	mg/Nm^3	mg/Nm^3	mg/Nm^3	mg/Nm^3
Dusseldorf	-	1,000(11)	9(11)	505(11)	9(11)	-
Paris:Issy	6.1-7.1	1,074-1,744(7)	-	126-139(7)	97-163(7)	-
Zurich:Hagenholz	7.7-8.4	531-840	11	219-220	-	-
Uppsala	6.4	22-114(10)	-	90-330(10)	-	-
Copenhagen:Amager	-	700-900(7)	-	200-300(7)	-	-
Anonymous French Plant(1)	8.8	430(7)	-	82(7)	40(7)	2.6(2)

(1) At the anonymous French plant, the sum of organic acids, aldehydes, ketones, alcohols, phenols, polyphenols, aliphatics, and cyclic and polycyclic compounds was 2.6 mg/Nm^3.

(2) Other organic compounds of N, S, and Cl totaled 0.2 mg/Nm^3.

Conversion to get ppm: HCl, multiply mg/Nm^3 by 0.62
HF " " " 1.12
(OC, 32F) SO_2 " " " 0.35
NO_x " " " 0.47 (as NO_2)

Precipitator Maintenance

Reliability of ESP's has been excellent except where the inlet gases have been too hot: above about 250 C (482 F). This has caused very rapid corrosion and deterioration of the precipitator. In most cases this overheating has been caused by an unanticipated increase in the heat value of the municipal refuse or wearing grate systems. Then if the boiler heating surfaces were not amply designed to cope with the resulting excessive heat release in the boiler-furnace, the gases pass on to the precipitator at high enough temperature to cause serious corrosion. In some cases this overheating may not occur until toward the end of a long period of operation when the heating surfaces are heavily coated by ash. Many plants then shut down for through boiler cleaning, usually after 3000 to 4000 hours.

Gases

Some attention is now being given to controlling gaseous emissions - HCl, HF and SO_2. However these gases are not emitted in high concentrations, and their ambient levels in the vicinity of even the largest plants is probably so low that no attempts have been made to measure nor to estimate them continuously in the surrounding air. Instead their control is now being considered just because they are perieved to be a problem. At present only in West Germany are new or modified plants now required to control gaseous emissions to the following levels (at 0 C, 32 F, corrected to 7 percent CO_2):

HCl:	100 mg/Nm^3 (62 ppm)	0.083 lb/1000 lb gas
HF:	5 mg/Nm^3 (11 ppm)	0.008 lb/1000 lb gas
SO_2	500 mg/Nm^3 (175 ppm)	0.46 lb/1000 lb gas

Accordingly only in Germany are scrubbers being tried. None was working satisfactorily at the plants visited. However, except for the very major maintenance problem always caused by the corrosiveness of acidic scrubber water, air emissions of HCl can probably eventually be controlled because it is highly soluble in water. HF should also be absorbed in a scrubber but the scant data available on HF emissions indicates that the German limit of 11 ppm at 7 percent CO_2 is readily met without scrubbers . Similarly, the sulfur content of refuse is so low and the probable capture of 25 to 59 percent of the sulfur by the alkalis in the ash means that SO_2 control will often be unnecessary to meet the 175 ppm emission limit in Germany.

One vexing aspect of scrubbers is that the saturated gas leaving the scrubber often creates a highly visible white steam plume. It may actually be a very clean plume but its appearance calls attention to possible emissions. Also if conditions are such as to produce large water droplets in the plume the resulting "rain" will be acidic because no scrubber removes 100 percent of the acid gas. The solution to a white plume and its acid rain is to reheat the plume to about 80 C (176 F) by means of steam-heated heat exchangers. However, reheaters consume energy and are subject to plugging and corrosion. One practical solution to this problem will be used at Wuppertal. The plan is to scrub a major part but not all of the gas to a level surpassing the allowable limit, meanwhile bypassing the uncleaned portion of the hot gas to a mixing and reheat section. The resulting reheated mixture can then be discharged without visible plume or acid rain while still being within the allowable emission limit.

Measured Gaseous Emissions

Table A-36. shows the results of emissions measurements at selected plants.

Gaseous Emission Limits

Table A-37. shows the emission limits applicable to refuse burning in the countries visited.

So far only in Germany and Sweden is there any limit on gaseous emissions, and even in Sweden the value of 40 mg/Nm^3 (approx. 20 ppm) of total acid gases is not a limit but a signal: if a plant exceeds that emission level it must undertake a study of feasible means to control emission. Presumably then actual control requirements will depend on the cost of feasible control and whether the need for improvement in local atmospheric quality levels warrant that expenditure.

Trends in Emissions Control

As can be seen from Table A-37 and the prior discussion, particulate control in these plants is excellent and high standards are regularly achieved. There is no strong trend in Europe to further control particles nor to control gaseous emissions. Many agencies appear to be awaiting the demonstrated effectiveness and reliability of the acid gas scrubbers now going through normal problems of startup in Germany at Wuppertal, Krefield and Kiel. If these eventually prove out to be as effective, maintainable and cost effective as ESP's there will probably be a trend to apply them more widely, especially in densely populated areas where ambient pollution levels are high. On the other hand, since there are no data to demonstrate the specific needs for elimination of HCl and HF from the ambient air, if their removal turns out to be as formidable a task as SO_2 control has been for coal-fired plants, the control of HCl and HF emission may become limited to those situations where a specific measurable need can be shown.

Start-Up and Shut-Down Procedures

Detailed comments about such procedures were obtained at four facilities. Starting up a unit can take anywhere from 2 to 24 hours depending on how much the furnace had cooled from the last firing.

Often a light oil burner is used to preheat the boiler and electrostatic precipitator. A slight variation is that the oil burner is almost always kept on upon shut-down to prevent dew point corrosion of the boiler and electrostatic precipitator.

At some of the plants the importance of a uniform and controlled rate of increase in burning rate is recognized as an important factor in minimizing equipment overheating and elaborate procedures are specified to assure that objective.

TABLE A-37. EMISSION LIMITS, mg/Nm^3
(Parentheses indicate CO_2 level to
which the concentration is adjusted)

COUNTRY		PARTICULATES mg/Nm^3	HCl mg/Nm^3	HF mg/Nm^3	SO_2 mg/Nm^3
W. Germany		100(7)	100(7)	5(7)	500(7)
Switzerland		100(7)	500(7)	-	300(7)
France	1 tonne/hr	1,000(7)	-	-	-
	1-4 tonne/hr	600			
	4-7 tonne/hr	250			
	7-(15) tonne/hr	150			
	(a) over(15) tonne/hr	80 (?)			
Holland		100(7)	-	-	-
Sweden		180(10)	40(10) (b)	- (b)	- (b)
Denmark	small plants	180(10)	-	-	-
	large plants	150 (11)	1,500	-	1,500 (c)
USA		180	-	-	-

(a) Estimated from incomplete data. May be 150 mg/Nm^3

(b) Total acid equivalent - Exceeding this total, 40 mg/Nm^3 for all acid gases, feasible control system.

(c) SO_2 plus SO_3.

The conversions to volume units are:

HCl	multiply	mg/Nm^3	by	0.62	to get ppm
HF	"	"	"	1.12	to get ppm
SO_2	"	"	"	0.35	to get ppm

To convert particulates: mg/Nm^3 to grains/scf. multiply by .00043

CONCLUSIONS
(And Comparisons of
U.S. Versus European Practice)

The following conclusions are arranged in order of their discussion in the evaluation volumes and not in order of importance. Major conclusions have been presented in a previous section.

World Wide Inventory Of Waste-to-Energy Systems

- The "Battelle Worldwide Inventory of Waste-to-Energy Systems" shows (as of March 1979) 522 locations where daily operating plants have, are or will process waste into energy. Also included are several large pilot and demonstration plants.
- Were all waste-to-energy systems consuming bark bagasse, waste oil, waste solvents, etc., known, our estimate is that well over 1000 systems exist and operate on a daily basis.
- Very few of the plants opened since World War II have closed. Plants typically operate for 25 to 40 years.
- Plants have been producing electricity from household refuse since before the term of the century although not always continuously: Hamburg (1896), Paris (1903), Zurich (1904) New York (1905), etc. The European systems have been replaced by a succession of refuse to energy systems.
- On the average, there are two furnaces per system. Some systems have up to six furnaces.
- The average furnace capacity is 232 tonnes (255 tons) per day.
- During the 1977 survey period, the U.S.A. had about 9430 tonnes of installed capacity and was consuming less than 5000 tonnes per day in waste-to-energy systems. This compares to a 1977 worldwide capacity of 101,937 tonnes.
- This converts to 0.0436 Kg (0.0959 pounds) total generation per U.S. person per day. If plans hold true and there are not further closings, this per capita figure should rise to 0.1818 Kg (0.4 pounds) of waste per person per day converted to energy in the U.S.A. by 1983.
- Japan has more systems and processes more waste than any other country. However, due to the high moisture content, very little useful energy is produced for sale.
- The Central European countries of West Germany, France and Switzerland have concentrated on high temperature steam systems for electrical production and district heating.
- Scandanavian countries use more refractory wall furnaces with waste heat boilers to produce hot water for district heating.
- Sewage sludge is dried and usually disposed of by the energy in refuse in 25 co-disposal systems worldwide.

- The U.S.A. inventory shows 31 systems that are major pilot plant or demonstrations.
- In the U.S. we have tried to develop new approaches to enjoy recovering while the remainder of the world has continued to build mass burning energy recovery systems.

Communities and Sites Visited

- Generally speaking, the sampling of 15 European communities is a fair representation of those U.S. communities that might undertake resource recovery with respect to collection areas, terrain, boundaries and population.
- Waste shed populations served by single plants range from a winter population of 20,000 in Dieppe to a year-round population in Paris.
- Many of the plants are most attractively designed, landscaped and located in residential or downtown business areas.

Separable Waste Streams

- This report, while mainly concerned with the treatment of household, commercial and light industrial waste, also discusss treatment of other waste streams within the same plant gate. The total list follows:
    - Household, commercial and light industrial (typical garbage truck loads)
    - Bulky household and large industrial waste
    - Waste water and sewage sludge
    - Source separated material (paper, bottles, etc)
    - Materials from front end separation - but without shredding (white goods, tires, copper in motors)
    - Waste oils and solvents
    - Industrial chemicals and hazardous wastes
    - Animal waste
    - Street sweepings
    - Construction, demolition debris and ash
    - Junk automobiles
- Many facilities have been planned with the various component activities for synergistic benefits.
- One example is the odors that are collected in a new rendering plant and are piped 100 feet to the refuse fired energy plant for destruction.
- Another example are the seven plants out of thirty viewed that use the energy content in refuse to dry sewage sludge prior to burning the sludge or land disposal.
- Finally, there are industrial and hazardous waste processes needing a high temperature and long residence time. Afterburning may be offered by a high temperature refuse furnace.

Collections and Transfer Stations

- Compared to America, there is more collection in Europe by the public sector.
- In several cities there is labor representation in traditional management functions.
- There are occasional computerized systems for route management, fiscal control and billing.
- There is a clear trend away from the open top metal refuse container in favor of rubber, plastic or paper containers.
- As in America, collection costs represent 70 to 90 percent of the total solid waste management costs.
- Assessment methods for collection and disposal vary widely from city to city.
- European collection vehicles have similar features, options and size ranges as in the U.S. However, due to smaller and winding streets, the size distribution is different. This results in a smaller average size vehicle.
- Collections are made 5 or 5-1/2 days per week. Collectors work 5 to 8 hours per day.
- Due to the increasing energy value of refuse, and limited heat capacity per furnace many plants will no longer accept "hotter" industrial solid waste. (pallets, cardboard, rubber and plastic trimmings) some systems wet this "hotter" waste before burning.
- Transfer station systems are being developed in Europe as in the U.S.

Composition of Refuse

- While there will be excursions below and above this range, the moisture content normally varies from a low average of 22.5 percent to a high average of 32.5 percent. The average among six facilities was 27.1 percent.
- European refuse has been rapidly approaching the composition of American waste as Europe has continued to "modernize" its way of life.

Heating Value of Refuse

- Because of the hydrogen content in refuse the higher heating value (HHV) conventionally used in the U.S. is roughly 7.0 percent higher than the lower heating value (LHV) as used in Europe.
- Recently the lower heating value averages varied from 1600 to 2800 Kcal/kg (2,850 to 5,000 Btu/pound) (6690 to 11,700 Kj/Kg). Simply adding 7 percent increases this to (3050 to 5350 Btu/pound). Thus today, European refuse contains almost as much energy as does American waste. This is a major shift from 25 years ago.
- The heating values, which have risen dramatically since 1945, are expected to begin stabilizing as citizens become more

conservation conscious, as petroleum becomes more precious and as material needs become satisfied.

- The dramatic rise in heating values has adversely affected facility performance. Boiler tube corrosion has increased. Downtime is up as well as maintenance costs. Many units have eventually been derated. As inferred above some 10 or 15 year old plants have discontinued receiving "hotter" industrial waste in an attempt to reduce the overall average heating value to design values.
- "Hotter" waste is inherently neither good nor bad. However, the designer must have a correct prediction of what his unit should expect over its reasonable life.

Refuse Generation and Burning Rates Per Person

- Most facilities viewed accept household, commercial and light industrial waste for burning at about these rates:
  - 318 kg per person per year (household and light commercial)
  - 45 kg per person per year (other commercial and light industrial)
  - 363 kg per person per year (total normal)
  - 800 pounds per person per year
  - 1.00 kg per person per day
  - 2.2 pounds per person per day

Development of Visited Systems

- The primary motivation for constructing refuse to energy plants in Europe has been to replace an existing landfill, compost plant or incinerator or to add additional incineration with heat recovery capacity. However, dramatic changes in the world energy supply will affect future attitudes as waste-to-energy.
- At none of the 15 major and 15 minor visited plants did anyone indicate to these authors that the primary motivation was connected with energy i.e. cost savings from free fuel, energy conservation or unavailability or other energy forms.
- Citizen and elected local official's perception of harmful effects from landfills is greater in Europe than America. This U.S. perception may be changing due to relevations about the "Love Canal" at Niagra Falls. Relevations that 60 to 80 percent of the American municipal waste landfills have accepted hazardous waste are also bound to increase the American citizen's perception of the hazards of untrolled landfilling.
- Many Europeans in moderately populated areas have greater concern for the destiny of land than Americansninisimilar areas.
- For many years, European federal governments have energetically supported refuse-fired energy plants at the same time that the U.S. Public Health Service and USEPA were

innovatively developing and encouraging the sanitary landfill concept.

- A corollary is that because many Europeans did not learn about or develop enthusiasm for the sanitary landfill, they turned to one of the other two key disposal alternatives: either composting or refuse to energy plants.
- Many European equipment vendors have not joined the American thrust towards refuse derived fuel and co-firing and hence such technical options have not been readily commercially available in Europe. Many of these vendors have expressed the following attitudes toward co-firing of refuse and coal, resulting in little continental enthusiasm. These authors are journalistically reporting actual attitudes and do not necessarily attest to the scientific validity of the statements:
    - "You should not burn refuse in the same combustion chamber with fossil fuel (coal, oil or gas). The high temperature of the fossil fuel will melt the fly ash. This fused and sticky fly ash will hit the wall or superheater tubes and instantly freeze a hard deposit that quickly reduces thermal efficiency. The more brutal tube cleaning methods needed will likely break large and hard deposits off thus leaving bare tubes now exposed to new corrosion. Many refuse furnaces equipped with auxiliary waste oil jets no longer use them - even though the waste oil may be free."
    - "Front-end preparation systems have a history of jams and other mechanical problems that reduce reliability and increase costs."
    - "Some Americans are under the false impression that a homogeneous fuel is needed for steady steam output. Our European systems do not need a uniform fuel. Attemperators (desuperheaters) and temperature sensing analog computers can carefully control steam temperatures to plus or minus 5 C. degrees.
    - "Explosive material in a shredder can cause explosions and fires inflicting destruction and occasionally loss of of life. The same explosive material in a furnace explodes usually without harm to the furance/boiler. (During the tour Battelle heard stories of explosions but no incidents of damage were reported to the authors.)
    - "Why do the Americans waste all that effort and cost in preparing the refuse. We just throw it into the pit, mix to a relatively uniform charge and drop it into the furnace hopper."
- In general, net operating costs per ton, after sale of resources recovered, have always been two to four time greater in a refuse to energy plant than in a landfill of prevailing practice at the time (of design or of construction).
- Regarding leachate, the U.S. approach has been to "correct" the problem by operating a better landfill. Europe's approach

has been to "avoid" the problem by burning the refuse and recycling the ash into useful products.

- Composting, very fashionable in Europe 10 to 20 years ago, has fallen as a chosen alternative because large volume, consistent product markets could not be maintained.
- In five of the visits, the plant was a replacement for refuse to energy plants that had served the community for many years. Satisfaction with refuse to energy operations of over 8 decades naturally enforces the momentum to continue with resource recovery. Hamburg, W. Germany has been producing electricity form refuse since 1896; Zurich since 1903.
- In summary the European attitude might be stated as follows:
  - "We don't like landfills
  - We don't think that a compost product can reliably be sold
  - American type front-end resource recovery seems to be needless because of the high processing cost, low materials revenues and that the energy plant doens't need the uniform fuel
  - So what's left?
  - Refuse fired, mass burning, energy production
  - If we have to pay more for proper disposal, so be it."
- We predict that in time, Europeans wil learn more about the advantages of a sanitary landfill. Perhaps also in time, the American front end processing systems utilizing refuse derived fuel (RDF) will mature and be attractive to European decision makers as a reliable and economical alternative.
- There is one sour note regarding future refuse to energy systems. The Swedish Government has adopted a policy of disfavoring further construction of refuse to energy systems. The SO_2 acid fallout is extensive in Sweden. About 10,000 lakes are "dead" because of an acid condition and more lakes are affected each year--primarily from sulfates due to fossil fuel (coal and oil) burning throughout not only Sweden but all Europe. There is concern about mercury already in some lakes from industrial wastes and in batteries and florescent tubes evaporated in refuse burners. Some claim that this mercury will more quickly convert to more readily assimilated methyl mercury when in these acidified lakes.

Total Operating System

- The report presents single tables which show for a unit of time, tons refuse processed, ash output, energy output, efficiency, operating hours, steaming rate, air pressure, etc. A detailed review of these tables with concentration on ratios between operating variables should improve the reader's understanding of the total operating system and how one activity affects another.

Organization and Personnel

- Each of the 30 systems visited in Europe was owned by either the local municipality or a not for profit authority. Of the 15 plants studied in detail, cities own 8, authorities own 6, and a nationalized electric company owns one. To our knowledge, private enterprise does not own any daily operating resource recovery systems in Europe consuming municipal waste.
- The 120 observed job titles can be condensed into 55 personnel categories.
- Potential economics of scale for large plants were often negated by establishing too many job categories and placing too many people into them.
- Rather than hire permanent employees, many plants extensively use outside services.
- The program of education, training and experience varies among countries. The Germans have a very rigorous program of schooling, navy or merchant marine boiler room experience, more schooling etc. Other countries however emphasize on-the-job training.
- The majority of furnace/boiler operators and plant managers have had sea experience.

Economics

Capital Investment

- Capital investment costs per daily ton capacity have increased 5 fold during the past 10 years. The 1960-1968 "capital cost per daily ton" ranged from $13,000 to $15,000 at three surveyed plants. The average for all 15 plants was about $35,000. The three later plants built in 1975 and 1976 averaged about $70,000. Plants in the early 1980's could initially cost over $100,000 per daily ton capacity.
- Of special note is that the three co-disposal systems (Krefeld, Horsens, and Dieppe) have higher than average capital costs. Considering the accompanying equipment, this is understandable.
- Seven reasons are discussed as contributors to this dramatic rise:
  - Inflation
  - Exchange rate devaluation
  - Corrosion protective equipment designs
  - Architecture and landscaping for neighborhood acceptance
  - More complex energy use systems
  - More air pollution control equipment
- American systems, for the same point in time, were usually less expensive than European systems.
- The American systems do not have as many "bell and whistle" design features as the European systems.
- The American purchaser has not previously feared corrosion enough to demand protective features.

- The American buyer often concentrates more on the lowest bid while the European buyer prefers a reliable system that he and the community can be proud of.
- Most European systems have very aesthetic features of architectuure, landscaping, conference rooms, offices, shower and locker rooms, etc.
- There are enough systems in Europe that personnel can choose among the many plants. Decision makers believe that the aesthetics, safety and worker comfort features are needed to attract and hold qualified employees.
- The essential difference, however, is momentum. With 275 systems to visit and be familiar with features, the European buyer knows and appreciates his options. To some extent, there may be peer pressures to have an excellent system. We Americans have not been exposed to enough facilities to have developed the same Continental appetite.

Expenses, Revenues and Net Disposal Costs

- Communities that have insisted on extra "chute-to-stack" design and operating features to increase reliability have benefited by having lower net disposal costs.
- The four refractory wall furnace/waste heat boilers surveyed each had net disposal costs lower than the average for all 15 plants surveyed. Hence American buyers should think also of the refractory wall furnace and waste heat boiler when discussing the "European Technology".
- The plants averaged $27 per ton for total gross expenses.
- Removing the small and most expensive plant at Werdenberg yields an average of $24.33 per ton total expense.
- With the exception of Werdenburg, there seems to be little effect of plant capacity on total expenses per ton of refuse processed, i.e., there seems to be little if any economy of scale.
- Revenues from sale of energy averaged about $7.50 per ton throughput.
- All 5 of the 15 systems receiving the highest revenue per refuse input ton are providing energy to district heating systems. Their average revenue is $9.76 per ton.
- All 5 of the 15 systems receiving the lowest revenue per refuse input ton are adversely affected by very competitive fossil fuel or nuclear electrical power stations. Their revenue averaged $5.30 per ton.
- As the price of conventional fossil fuel rises higher than the average inflation rate, there is a potential for the revenue from energy sale to rise, resulting in declining net disposal costs and tipping fees.
- The 1974 Nashville Thermal Transfer Corporation with a net disposal cost of $2.00 per ton and the new 1980 Akron system having estimated costs of $3.50 per ton have excellent net costs to tax payers because of the high steam price paid by district heating customers of $6.00 and $5.50 per 1000 pounds

steam respectively. Assuming 5,000 pounds of "reasonable quality" steam can be produced from one ton of refuse, revenues at Nashville and Akron would be around $30.00 and $27.50 per ton of refuse. In no way could such energy revenue be raised by sale of electricity alone. No European system observed had such low net disposal costs.

- Those plants that processed their ash into ferrous scrap and road building aggregate received about 40 cents per ton in revenue but avoided about $1.00 per ton in landfilling of ash per refuse input ton.

Refuse Handling

- For furnace feeding all plants observed have the system of "pit crane mixing and loading into the feed hopper". No plant observed has the American system of dumping refuse onto the floor, moving it by front end loader onto conveyors, etc.
- Crane operators are situated in the stationary control rooms along the front side or back of the pit. This is in contrast to many American systems where the cab is located on the crane. European designers have concern for operator safety should there be a pit fire.
- Most modern plants, especially in Scandinavia, use plastic-magnetic cards inserted by truck drivers on entry as part of the automatic weighing and billing system.
- Large plants usually have a separate weighing station while very small plants have the weighmaster actually inside the plant control room.
- Many plants shear bulky combustible objects (desks, mattresses, couches, etc.) in a powerful scissors shear for size reduction to pieces less than 1 m (1 yd) in length.
- Many plants have large separate containers for receipt of ferrous metals, cardboard, bottles which can be recycled.
- Source separation progrms for newspapers, cardboard, bottles, cans, etc. will not substantially detract from energy production.
- Many Northern and a few Southern European plants have enclosed tipping halls.
- Most systems have doors between the tipping floor and the pit (1) to keep odors inside when the system is closed, (2) to permit a higher negative pressure and thus better odor control when operating and (3) to increase the effective volume of the pit for refuse storage against a few of the closed doors.
- Most pits are designed to hold 3-5 days volume of refuse.
- Most pits are equipped with fire control devices.
- Most plants have at least two cranes to provide redundancy.
- A key crane operator function is to mix incoming refuse prior to loading into the hopper.

Grates and Primary Air

- Burnback is common in hoppers and feed chutes. Some are water-cooled.
- Thirty-five (35) independent grate systems are available from vendors.
- European grates are designed for "mass burning", i.e. the refuse is burned essentially as received from the typical household garbage truck.
- The only commerically operating municipal refuse systems in Europe known to these researchers which are not mass burners are in England. One is a suspension fired boiler at the IMI plant in Birmingham, England. The other is a Portland Cement plant in England.
- Most European grate vendors are skeptical regarding the long-term commercial viability of suspension fired systems instead of grate systems. As explained before one concern is the additional costs of preparing the refuse derived fuel (RDF). Another concern expressed by many vendors is the high temperatures usually experienced when co-firing with a conventional fuel such as coal, oil or gas. The flue gas temperature and sticky deposits form on boiler tubes that reduce heat transfer efficiency and occasionally can block sections of boilers. When these deposits are finally blown off, the unprotected surfaces suffer increased "high-temperature corrosion".
- Grates have the four primary functions of (1) supporting the burning refuse, (2) agitating the refuse for better combustion, (3) moving the refuse downward and out of the furnace, and (4) distributing the primary (underfire) air.
- Observed grate capacities ranged from 3.33 tonnes (3.7 tons) to 24.6 tonnes (27 tons) per hour. Other furnaces, not viewed, have design capacities ranging from less than 1 tonn per hour to as much as 44 tonnes per hour.
- Careful design and control of primary and secondary air systems is essential for good combustion control, especially if high temperature steam is to be produced.
- Concentrated amounts of high energy-containing material may (1) melt the cast iron grates or (2) cause fires underneath the grates. Examples are magnesium chips, aluminum, plastic film, butter, etc. Progressive plant managers have suggested industrial waste source separation programs.
- Grates need to be designed so that mechanical wear does not create large air spaces that reduce primary air pressure. This can cause serious loss of control of combustion. Carbon monoxide (CO) forms and can (according to some theorists) accelerate tube corrosion. Also unburnt carbon may leave the furnace in exit gas or bottom ash.
- Some vendors believe that combustion air should be held constant, while the feed is controlled in an effort to keep the steam temperature constant.

Furnace Wall

- Prior to 1957, all European refuse furnaces were lined with refractory and not with water tube walls.
- Beginning in 1957 with the Berne, Switzerland plant, the use of water tube walls as the furnace enclosure has increased substantially.
- Earlier furnaces had carbon steel exposed bare tubes. Later furnaces have low alloy steel tubes, usually protected on the flame side by plastic refractory held in place by welded studs.
- Many integrated furnace/boiler designs result in half of the energy removed going into the wall tubes while the other goes into the convection banks.
- Refractory wall furnaces with waste heat boilers, being less expensive, are often appropriate for hot water or low temperature steam applications.
- Water tube wall furnace/boilers producing high temperature steam are usually chosen for high temperature steam systems producing electricity efficiently.
- The remarkable increase in refuse heating value since 1945 has exerted substantial influence on furnace wall design. Even controlled air injection or flue gas recirculation alone was not enough to lower flue gas temperature so that older equipment would survive.
- Many furnaces have extended life if the lower furnace walls near the grate can be cooled.
- Some plants use silicon carbide bricks just above the grate to prevent slag adhesion.
- Increasingly water-tube walls are of the membrane or welded fin design to reduce air infiltration and to keep tubes in line rather to permit some tubes to bend in or out. Sootblowers with a fixed blowing pattern can erode a displaced tube that is over-exposed to the steam jet.
- One manufacturer, Volund, often uses a rotary kiln after the grate furance to ensure a complete burnout. Another, Bruun and Sorensen, uses a vertical, refractory, cyclonic afterburner chamber.

Secondary (Overfire) Air

- To obtain complete combustion, and to abate smoke and possibly corrosive carbon monoxide formation, the unburned volatile (or pyrolysis) gases rising from the fuel bed must be mixed rapidly with ample oxygen. This mixing must be done relatively near the fuel bed with the assistance of high velocity secondary air jets.
- There is a trend away from side wall jets and towards the front and rear wall jets.
- Care must be taken to avoid intense burning of volatile gases along the wall near the air jets.
- Usually the quantity of overfire air supply ranges from 10 to 25 percent of the total combustion air: primary plus secondary.

Boilers

- Most superheaters suspended at the top of the first pass are subject to increased chloride corrosion because of overheating of chlorides in the ash deposits, especially when long flames reach up to them during occasional "excursions" characteristic of mass burning.
- Long, water-cooled first and second passes followed by a superheater in the third pass appear to be very important in keeping the ash deposits on the superheaters cool enough that chloride attack is minimized.
- Refractory wall furnace/waste heat boilers producing hot water or low temperature steam exhibited almost no corrosion.
- There are a few examples of systems producing high temperature steam where corrosion is minimal. Some such systems have operated over five (5) years without a tube failure. They are characterized by having numerous metal wastage (erosion and corrosion)preventive design features and operating practices.
- At this time, 1977-1978, it appears that the current "best" boiler-furnace design in use for large, high pressure units is the completely water-tube-walled furnace and radiant section, studded and coated with thin plastic refractory in the intense burning zone, followed by one or more long, open, vertical radiation passes preceding a convention-type superheater and boiler-convection passes and economizer.
- Roughly 180 units world wide have an Eckrohr (translated to "corner-tube") boiler as licensed by Professor Vorkauf of Berlin. The Eckrohr design can stand alone as a waste heat boiler following the furnace or can be placed in an integrated furnace/boiler.
- Recent work for EPA by the Battelle Columbus Laboratories postulate that corrosion can be lessened due to an interesting chemical phenomena. Sulfur (in coal, oil, sewage sludge or contaminated methane gases from landfills) has the effect of forming relatively harmless deposits that prevent chlorine from being so corrosive.
- An emerging newer boiler design is to follow the tall water-tube-walled combustion chamber by a long superheater, boiler convection section and economizer. This is called the "dacha" boiler (after the female dashund dog) because of its extended horizontal configuration. This permits tube cleaning by mechanical rapping and eases the labor of tube replacement when needed.

- Nine of the fifteen plants visited employ superheaters to heat saturated steam to temperature levels that enable relatively efficient electrical production. The other six plants do not generate power and therefore have no superheaters.
- A protective ash coating ranging between a minimum of about three mm (.12 in) and a maximum of 15 mm (0.6 in) appears to be in the desirable range.
- Above some ash deposit temperature, perhaps 744 C (1300 F), the protective deposit becomes chemically active and corrosion begins.
- Burning either too much normal refuse or a normal volume of "hot" industrial waste can overheat the furnace/boiler and cause corrosion.
- There are several theories of corrosion causes. Three causes stand out: high temperature, HCl and CO. Investigators do not agree among themselves as to the "real" phenomena. Interestingly, the successful systems (those producing high temperature steam with little or no corrosion of boiler tubes) have design features and operating practices consistent with even conflicting theories.
- The report identifies over 33 design features and operating practices that reduce corrosion. A prudent design/operation will selectively use more than 10 features and practices but not waste money by utilizing all of them.
- Superheater life can be enhanced by use of alloy steel containing chromium, molybenum and occasionally nickel.
- Alloy shields and bead-welded coatings can also extend tube life.
- Attemperators (desuperheaters) located between superheater bundles can control steam temperature, metal temperature and thus ash deposit temperature to prevent high temperature chloride corrosion.
- Plants not able to utilize all of the produced steam must condense the steam in air-cooled or water-cooled condensers.
- Excessive use of high-pressure steam soot blowers is a common source of tube erosion-corrosion.
- Other boiler cleaning methods less threatening to boiler tubes are available such as mechanical rapping, shot cleaning, and compressed air soot blowing.

- One plant, Krefeld, located in a SO_2 non-compliance area was required to install (1) an field ESP for particulates, (2) a one stage wet scrubber for HCl and HF and (3) a second stage wet scrubber for SO_2.

- Technically, the U.S. standard for particulates of 0.08 grains per standard cubic foot adjusted to 12 percent CO_2 (180 mg/Nm^3) is bettered by many plants achieving 0.03 to 0.05 g/SCF. Some Japanese plants achieve even 0.01 g/SCF upon startup.
- The U.S. standard of 0.08 g/SCF is technically very reasonable and achieveable.
- The requirement of scrubbers for HCl removal for new plants greatly increases original capital investment and has slowed implementation of New RFES's in Germany.
- The Europeans seem to be more concerned with heavy metals and organics in landfill leachate and groundwater than they are with traces of heavy metal oxides from the refuse fired energy plant stack.
- Of the German plants visited having scrubbers, none was yet working adequately and without corrosion.
- Saturated gas leaving the scrubber often creates a highly visible white steam plume that often may upset the neighbors. As a result most systems having scrubbers are trying to use a flue gas reheat system but reheater corrosion is often a problem.
- Water pollution control is often not an issue at plants with scrubbers. Dirty process water can normally be disposed of in the ash chute quenching system.

Start-Up and Shut-Down

- Start-up and shut-down procedures are carefully patterned to reduce corrosion of boiler and electrostatic precipitators (ESP). Often standby oil burners and steam boilers are used.

Supplementary Firing and Co-Firing of Fuel Oil, Waste Oil, Solvents and Coal

- Supplementary firing of fuel oil, waste oil or solvents is preferred when there is a need for emergency backup, routine weekend uses, preheating upon startup, prevention of dew point corrosion, legally destroying pathogens and other hydrocarbons, and for routine energy uses when the refuse fired energy plant is down.
- However, supplementary firing may not be necessary when the energy user has his own alternative energy supply, when electricity is fed to a large electrical network, when treatment of refuse or sewage sludge can be postponed several days or when a regional plan mandates waste oil treatment and burning at another facility.
- When supplementary standby capability is required, the plant can usually sell its steam at a premium price.
- Many vendors (but not all) believe that no fuel other than refuse should be burned in the same chamber with refuse.
- In 1977, no continental European plant co-fired refuse and coal in the same combustion chamber. The only facility anything like St. Louis, Ames, Chicago S.W., Milwaukee, etc was located in Birmingham, England at the IMI factory.
- Many European vendors suggest that if refuse and a fossil fuel are to be fired in the same system they be fired in separate combustion chambers. Flue gases can later be united before entering the boiler convection section.

Air Pollution Control

- The development of the modern water-tube wall furnace/boiler was in part due to the need for proper air pollution control.
- Flue gases can be cooled with massive air dilution, water spray or boiler.
- Energy recovery in boilers is the preferred cooling method if a reasonable market can be assured or anticipated.
- The almost universally accepted method for particulate removal is the electrostatic precipitator.
- Scrubbers alone have failed to meet the particulate standards.
- We observed what is believed to be the only baghouse control on a commercial refuse fired energy plant, at Neuchatel, Switzerland. The efficiency was only moderate and the plant had suffered extreme problems with corrosion.
- Reliability of electrostatic precipitators (ESP) has been excellent except where the inlet gases have been too hot.
- Entering flue gas temperatures must be kept above 177 C (350 F) to prevent dew point corrosion of electrostatic precipitators (ESP).
- Entering flue gas temperatures must be kept below 260 C (500 F) to prevent high temperature chloride corrosion.
- The most stringent air pollution control standards have been set for West Germany. The standards are much more stringent than in the U.S. Many persons questioned the health effect justification for the standard. Other European Federal environmental agencies have carefully viewed the standard and have either accepted the particulate but rejected the tight gaseous (HCl, HF) control or have adopted a wait and see attitude.

WORLDWIDE INVENTORY OF WASTE-TO-ENERGY SYSTEMS

The growing "Battelle Worldwide Inventory of Waste-to-Energy Systems" in March 1979 shows 522 separate systems where solid waste was, is or will be converted to energy from 1896 to 1983. The vast majority of these consume municipal solid waste composed of household, commercial and light industrial waste. With this publishing, we are aiming for complete coverage of municipal waste-to-energy systems. Complete coverage of systems using municipal solid waste as energy to evaporate the moisture in municipal sewage sludge is also a goal.

This chapter concludes with Table B-6; the inventory itself.

While this contract focuses on Europe, the inventory includes plants from the entire world (U.S.A., Japan, Brazil, etc). Interestingly, Japan has more plants and more tonnage capacity than any other country in the world.

Battelle has for six years been a collector of inventory lists and encourages others to send lists and updations to the principal author of this report.

Exclusions

Systems converting industrial waste (sludges, slurries, paste, liquid chemicals, etc.) to energy are included where possible. Only a few of the numerous bark and bagasse waste-to-energy systems are included. Systems recovering materials and not energy are usually not included. Daily operating systems of every size are included. However, experimental or demonstration units are only included if system capacity is above 50 tonnes (55 tons) per day. Only a few of the many small modular package incinerator/heat exchanger-boilers are included. Sludge incinerators fired with oil or gas are excluded.

Battelle has also been compiling an even greater listing showing about 750 places where money has, is or will be spent to advance the various technologies. Many companies have developed new technologies which have been tested in bench models or small pilot plants. Other notations reflect communities or companies initiating feasibility studies. These systems are not included in Table B-6.

Number and Tonnage Capacity

Results of the 522 system inventory are statistically summarized by analyzing only 368 currently operating systems that have complete enough information. Hence Table B-1 understates the true situation by 154 systems. As time progresses we desire to complete the information and increase the numbers in the table. About 24 of these 522 systems identified have closed. Closures fall generally into several categories. Some commercial systems that have operated 25 to 40 years close as part of normal retirement. We know of only one commercially operating European system (Gluckstadt, West

TABLE B-1. SUMMARY OF WORLD WIDE INVENTORY OF WASTE TO ENERGY SYSTEMS (1896 - 1983)

	No. of Systems	No. of Furnace Units	Installed Capacity Tonnes/Day	Area (KM)$^{2(a)}$	Population 1,000's in 1972, 3 or 4$^{(a)}$	Tonnes/ Day/KM^2	Lbs/Day /Capita	MT/Day per Furnace
Argentina				2,776,641	23,920			
Australia	1	2	520	7,686,849	13,268	0.0676 10^{-3}	0.086	260
Austria	2	5	1,320	83,848	7,520	0.157	0.386	264
Belgium	2	5	1,048	30,507	9,711	0.0344	0.237	210
Brazil	2	4	660	8,511,918	105,137	0.0775 10^{-3}	0.014	165
Canada	3	10	2,800	9,976,140	22,047	0.2807 10^{-3}	0.279	280
Czechoslovakia	1	3	864	127,870	14,580	0.0068	0.130	288
Denmark	35	57	6,348	43,033	5,130	0.1475	2.722	111
Finland	2	4	640	337,007	4,660	0.0019	0.302	160
France	26	54	11,858	551,598	52,350	0.0215	0.498	220
Germany, FGR	39	94	23,389	248,160	61,970	0.0942	0.830	249
Hong Kong	3	12	3,216	1,013	4,160	3.1757	1.701	266
Hungary	1	4	1,440	93,030	10,410	0.0155	0.304	360
Italy	24	56	9,997	301,223	55,262	0.0332	0.398	179
Japan	85	204	44,581	371,855	108,710	0.1199	0.902	219
Luxemborg	2	3	600	2,587	350	0.2319	3.771	200
Monaco	1	2	280	2	30	154.4	20.533	140
Netherlands	6	23	8,637	36,757	13,500	0.2350	1.408	376
Norway	8	11	206	324,217	3,960	0.6354 10^{-3}	0.114	19
Singapore	1	3	1,440	585	2,190	2.4601	1.447	480
Spain	4	5	1,158	504,745	34,860	0.0023	0.073	232
Sweden	24	45	5,456	449,790	8,144	0.0121	1.474	121
Switzerland	26	51	7,600	41,287	6,440	0.1841	2.596	149
United Kingdom	9	19	4,624	244,000	55,930	0.0190	0.182	243
United States	55	78	34,870	9,363,123	211,210	0.0041	0.400	492
U.S.S.R.	6	17	5,032	22,396,275	250,900	0.2247 10^{-3}	0.04	296
Total	368	771	178,584	64,504,060	1,086,349	0.0028	0.362	232

(a) The World Almanac and Book of Facts 1975.

Germany) built after World War II that has been closed. It was a refractory wall unit used for drying sewage sludge. There were several premature closings in the U.S.A. brought on by new air pollution control regulations. Several listed American pilot or demonstration plants have closed once they accomplished their objective of proving or disproving the project idea.

These systems have from one to perhaps six lines or furnace units. Our inventory show 771 such furnaces.

The 522 systems span a time frame of 1896 to 1982. The U.S.A. is expected to build three times as many waste-to-energy systems from 1977 to 1982 as it has built throughout its history. The 368 systems (771 furnaces) for which complete data was wastable were designed to consume 178,584 tonnes (196,442 tons) per day. The average furnace cpaacity is 232 tonnes (255 tons) per day.

Special effort was made to develop Table B-2 which is an analysis of operating plants in 1977 which can be used as a base point and coincides with the study tour. The U.S.A. capacity was 9430 tonnes out of a total 101,937 or 9.25 percent of the world capacity in 22 countries. Dividing by the total population (1,074,348,000) for those 22 countries, gives a 0.2 pounds of waste per person per day being converted to energy in countries that have at least one municipal waste-to-energy system.

The third column of Table B-2 was used to prepare Figure B-1. Municipal waste per person per day is portrayed for 22 countires ranging from 0.003 in the U.S.S.R. to 2.444 in Luxenborg. While Luxemborg might be a unique situation, Denmark at 2.304 and Switzerland at 1.982 certainly must be respected for their efforts in energy conservation through resource recovery. Thus the installed capacity is more than half the amount generated. The U.S.A. in 1977, however, was in a dismal position at only 0.0436 Kg (0.094 pounds) refuse per person per day being converted to energy. Even with the plants anticipated by 1983, this figure rises only to 0.1818 Kg (0.400 pounds) per day.

Table B-3 presents a closer look at the U.S. situation in 1977. The daily installed per tonne capacity was only 7912 tonnes at 18 system locations.

(We expects this number to be less because some of these systems are not consistently reported. i.e. Amarillo, Beverly, Braintree, Houston, Portsmouth)

Energy Use Patterns

Table B-4 by country presents the energy use pattern of those plants where information is available. Patterns vary widely from country to country as influenced by waste composition (H_2O and HCl), climatic conditions, attutudes, building codes, federal funding, utility regulations and prohibitions against ocean dumping of sewage sludge.

Japan has municipal waste twice as wet (55 percent H_2O) and three times more plastics (10-15 percent) than waste in America. As a result, energy left after water evaporation is severely limited. In addition the high presence of chlorine in the plastics potentially causes "high temperature chloride corrosion". This limits the steam temperature possible. While Japan has more systems (85) and more installeld tonnage capacity 44,581 tonnes than any other country, the useable and sellable

TABLE B-2. POUNDS OF MUNICIPAL WASTE CONVERTED TO ENERGY PER PERSON PER DAY BY COUNTRY CAPACITY WHEN PLANTS WERE SURVEYED IN 1977

	Capacity (MT/Day)	Population 1,000's (1976)	Pounds per Person per Day 1977	Ranking 1977	Ranking 1983
Argentina	0	25,720	0		26
Australia	520	13,640	.084	18	22
Austria	1, 320	7,510	.387	9	14
Belgium	1,158	9,890	.258	13	18
Brazil	660	109,180	.013	21	25
Canada	2,800	22,998	.268	11	17
Czechoslovkia	1,009	14,920	.149	14	20
Denmark	5,310	5,070	2.304	2	3
Finland	770	4,730	.358	10	16
France	12,690	52,920	.528	8	11
Germany (FGR)	28,149	61,500	1.007	7	10
Hong Kong	2,268	4,500	1.109	6	5
Hungary	0	10,600	0		15
Italy	6,711	56,190	.262	12	13
Japan	3,425	112,770	.067	20	9
Luxemborg	400	360	2.444	1	2
Monaco	0	30	0		1
Netherlands	8,637	13,770	1.380	5	8
Norway	210	4,030	.115	16	21
Singapore	0	2,280	0		7
Spain	1,158	35,970	.071	19	23
Sweden	5,456	8,220	1.460	4	6
Switzerland	5,720	6,350	1.982	3	4
U.K.	3,736	55,930	.147	15	19
U.S.A.	9,430	216,000	.096	17	12
U.S.S.R.	400	257,900	.003	22	24
Total	101,937	1,074,348	.209		

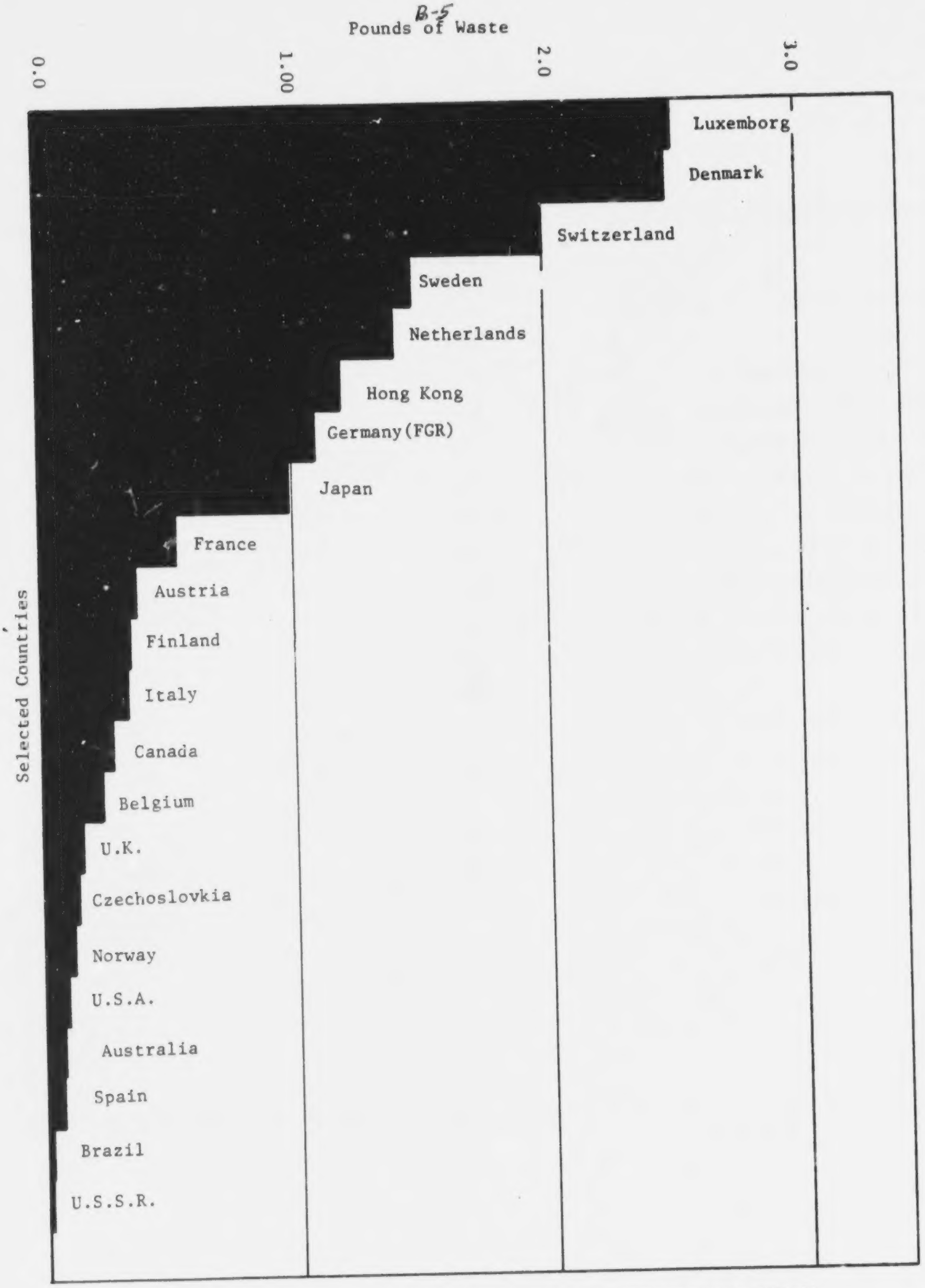

FIGURE B-1. POUNDS OF WASTE PROCESSED IN REFUSE-FIRED ENERGY GENERATORS PER CAPITA PER DAY IN SELECTED COUNTRIES (RATED INSTALLED CAPACITY)

TABLE B-3. U.S.A. WASTE-TO-ENERGY SYSTEMS OPERATING (TONNES/DAY)

	Capacity in 1977	Actual in 1977
Amarillo, Texas	218	
Ames, Iowa	182	
Baltimore, Maryland	727	
Beverly, Massachusetts	455	
Blytheville, Arkansas	41	
Braintree, Massachusetts	218	
Chicago, N.W., Illinois	1,455	1400
Franklin, Ohio	45	25
Harrisburg, Pennsylvania	655	500
Hempstead (Merrick), New York	545	
Hempstead (Oceanside), New York	682	
Houston, Texas	364	
Nashville, Tennessee	655	655
Norfolk, Virginia	327	120
North Little Rock, Arkansas	91	
Portsmouth, Virginia	145	
Saugus, Massachusetts	1091	550
Siloam Springs, Arkansas	16	
	7912	

TABLE B-4. THE WORLD'S USES OF ENERGY PRODUCED BY MUNICIPAL* WASTE TO ENERGY COMMERCIALLY OPERATING OR LARGE DEMONSTRATION SYSTEMS

	Unidentified Use or Hot Water Internal Use Only	Hot Water District Heating	Hot Water Or Steam Hospitals	Unidentified Use Or Steam Internal Use Only	Steam District Heating	Steam Industrial Process	Electricity Internal Uses	Electricity Export to Network	Air Cond.	Sludge Drying	Large Demonstration Commercial Processes Using RDF	Methane Gas or Pryolitic Oil	Heating Public Facilities	Heating Swimming Pools	Heating Green Houses
Argentina															
Australia															
Austria			1	1	1		2								
Belgium				1				2							
Brazil															
Canada					1	1	1	1	1						
Czechoslovakia						1									
Denmark		35			2					2					
Finland	1				2			1				2			
France				3	8	3		7		6					
German, FGR		7	1	2	23	6		31		4		1			
Hong Kong			2												
Hungary								1							
Italy	1			7		1		6							
Japan	61	1			1		12	4	1				18	7	3
Luxemborg								2							
Monaco				1											
Netherlands	1		2					2		1					
Norway						1		1							
Singapore								1							
Spain				2				2							
Sweden		13	4				3	1		2					
Switzerland		4		2	8	6	1	22		1					
United Kingdon		2						5			2				
United States				15	7	7		23	6	9	31	9	6		
U.S.S.R					6										
Total	64	62	6	38	59	26	19	112	8	25	33	13	24	7	3

* Municipal Waste is defined as Household, Commercial and Light Industrial Waste.

TABLE B-4. THE WORLD'S USES OF ENERGY PRODUCED BY MUNICIPAL* WASTE TO ENERGY COMMERCIALLY OPERATING OR LARGE DEMONS RATION SYSTEMS

	Unidentified Use or Hot Water Internal Use Only	Hot Water District Heating	Hot Water Or Steam Hospitals	Unidentified Use Or Steam Internal Use Only	Steam District Heating	Steam Industrial Process	Electricity Internal Uses	Electricity Export to Network	Air Cond.	Sludge Drying	Large Demonstration Commercial Processes Using RDF	Methane Gas or Pryolitic Oil	Heating Public Facilities	Heating Swimming Pools	Heating Green Houses
Argentina															
Australia															
Austria			1	1	1		2								
Belgium				1				2							
Brazil															
Canada					1	1	1	1	1						
Czechoslovakia						1									
Denmark		35			2					2					
Finland	1				2			1				2			
France				3	8	3		7		6					
German, FGR		7	1	2	23	6		31		4		1			
Hong Kong			2												
Hungary								1							
Italy	1			7		1		6							
Japan	61	1			1		12	4	1				18	7	1
Luxemborg								2							
Monaco				1											
Netherlands	1		2					2		1					
Norway						1		1							
Singapore								1							
Spain				2				2							
Sweden		13	4				3	1		2					
Switzerland		4		2	8	6	1	22		1					
United Kingdon		2						5			2				
United States				15	7			23	6	9	31	9	6		
U.S.S.R					6										
Total	64	62	6	38	59	26	19	112	8	25	33	13	24	7	1

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* Municipal Waste is defined as Household, Commercial and Light Industrial Waste.

energy output is rather small. Our records show that only 4 of these 85 systems produce enough high temperature steam for electrical production and sale. Twelve (12) systems produce only enough electricity for internal use. Heating swimming pools (7) green houses (3) and public facilities (18) are other energy uses. About 61 systems produce hot water for internal or other unidentified uses.

The United States (with 55 systems) has the broadest range of energy uses for systems between 1896 and 1983. Interestingly, 31 of the United States systems have have been major pilot plants or large demonstrations. This highlights a major difference between the U.S.A. and most other countries. The Americans have spent money looking for new systems while the remainder of the world has built systems based on the proven "European technology". Of note is the absence of hot water systems in the U.S. This is consistent with U.S. district heating practice of using only steam (in contrast to Denmark and Sweden). The single most common American energy use is production of electricity. The inventory includes 9 systems producing a methane based gas or pyrolytic oil. The inventory purposely excludes another 75 or so pyrolysis liquifaction, gasification, etc. developments that are not commercially relevant to include.

West Germany (FGR) has the most systems (39) of any European country. The Germans have concentrated on steam for electrical production, district heating and for industrial processes.

Denmark has (35) systems. Unlike the Germans, most Danish systems supply hot water for district heating.

Our records show France with 26 systems but none produce hot water. Comparatively France has led developments in sludge drying and destruction with 6 systems. Steam for electricity production and district heating is a common energy requirement.

Switzerland with 26 systems is ranked third behind Germany and the U.S.A. in production of electricity. Both steam and hot water district heating are prevalent.

Italian systems produce steam for electrical production or for only internal use.

Swedish systems supply hot water for district heating and government owned hospitals.

Furnace Size Distribution

Table B-5 shows the capacity distribution of furnaces in 25 countries that are now operating or will be by 1982. Most furances consume 5 to 10 metric tonnes per hour. However over 8 consume over 40 tonnes pgr hour per furnace. Japan again stands out with its 180 units in this 5 to 10 tonne per hour category. The largest furnaces are to be found in France, Germany and the United States.

TABLE B- 5. NUMBER OF FURNACES BY CAPACITY AND COUNTRY (CURRENTLY OPERATING AND PLANNED EXPANSION TO 1982) (METRIC TONNES PER HOUR PER LINE)

	0-5.0	5.1-10.0	10.1-15.0	15.1-20.0	20.1-25.0	25.0-40.0	40.1→
Argentina							
Australia			2				
Austria		3	2				
Belgium		5					
Brazil		4					
Canada			10				
Czechoslovakia			3				
Denmark	43	12	7				
Finland	4	2					
France	16	28	9	4			2
Germany, FGR	12	30	18	27	6	2	3
Hong Kong			13				
Hungary							
Italy	24	14	18				
Japan	6	180	60		6		
Luxemborg		3					
Monaco		2					
Netherlands		5	4	10	4		
Norway	10	1					
Singapore				3			
Spain	1	1	3				
Sweden	34	6	5				
Switzerland	33	14	2	3	1		
United Kingdom	2	7	10				
United States	8	12	8	4		9	3
U.S.S.R.		2	13				
TOTAL	193	331	187	51	17	11	8

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
ARGENTINA										
Buenos Aires II	Volund		H, C, LI						Energy(?)	Under construction in 1976
AUSTRALIA										
Sydney Waverley Woollahra	Von Roll		H, C, LI	2		260	520	1970	Energy recovered	
AUSTRIA										
Vienna	Von Roll	Water wall RFSG	H, C, LI	3	8.3	200	600	1963	Steam Electricity Hot water: hospital heat	
Vienna Spittela Heizbetriebe wien	Martin Waagner Biro Boilers	Water wall RFSG	H, C, LI	2	15	360	720	1971	Steam: 38.6 t/hr/line for district heating at 238 C, 32 bar Electricity: 2.34 MW	
BELGIUM										
Brussels Schaerbeck	Von Roll	Water wall RFSG	H, C, LI	2	8.3	200	400	1957	Steam: internal Electricity: network	
Brugge Syndicat-Intercommunal	Martin CNIM	Water wall RFSG	H, C, LI	3	9.92	216	648	1977	Steam: 27.9 t/hr/line at 400 C, 30 bar Electricity: 4.5 MW	Under construction in 1976
Willebroek	VKW	Water wall RFSG	H, C, LI	2	2.3	55	110	1972	Air preheating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
BRAZIL										
Sao Paulo Ponte Pequena	Martin	RFSG	H, C, LI	2	6.78	165	330	1959	Heats combustion air	
Sao Paulo Ipiranga	Martin	RFSG	H, C, LI	2	6.78	165	330	1967	Heats combustion air	
CANADA										
Hamilton	Babcock-Wilcox Detroit Stoker Gordon Sutton	RDF Suspension firing in water wall RFSG	H, C, LI	2		300	600	1972	Steam: 200,000 #/hr Saturated 251 psi	Materials handling being rebuilt 1978-79
Montreal	Von Roll	Water wall	H, C, LI	4		300	1200	1970	Steam Electricity	
Quebec City	Von Roll	Water wall	H, C, LI	4 (or 2		250 500	1000 1000)	1974	Steam: Pulp and paper mill Steam: District heating and air conditioning	
Toronto Ontario Centre for Res. Rec. Downsview		RDF	H, C, LI				300	1979	Experimental, tested kilns at Canada LaFarge Cement Co. Also used internally in boilers	
CZECHOSLOVAKIA										
Bratislava	VKW			3	12	288	864			
Dubova Petrochema	VKW	Rotary kiln	Acid resins Sludges	1	2.56	61	61	1976	Steam: 13 t/hr 15 Bar saturated	
Kaucuk Kralupy	VKW	Rotary kiln Waste heat boiler	Solids Sludge and Liquids	1	3.7 .2	89 5	89 5 94	1977	Steam: 18 t/hr 230 C, 15 Bar	
Povazske Strojarne	VKW	Rotary kiln	Solids, sludges Liquids	1	1	24	24	1978	Steam: 4 t/hr 12.5 Bar saturated	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./ Hr	Rated Capacity Per Line M.T./ Day	Rated Capacity Per System M.T./ Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
DENMARK										
Aalborg	B&S (Flynn & Emrich Rasmussen?)	Refractory wall RFHWG	H, C, LI	1	5.5	132	132	1968	Hot water: District heating	
Aalborg	Volund	Refractory wall Furnace Rotary kiln RFHWG	H, C, LI	1	7.5	180	180	1972	Hot water: District heating	
Aalborg	Flynn & Emrich E. Rasmussen	Refractory wall Furnace RFHWG	H, C, LI				312	1968	Hot water: District heating	
Aarhus-North	B&S	Refractory wall RFHWG Rotary drum for sludge	H, C, LI Sewage sludge	2	8	192	384	1979	Hot water: District heating Flue gases: sludge drying Sludge burning	
Aarhus-Tilst	B&S	Refractory wall Furnace RFHWG		1	6t/ 8 hr		6	1969	Hot water: district heating	Operated one shift per day
Albertslund	B&S Destructor	Refractory wall Furnace RFHWG	H, C, LI	1	3.5	84	84	1968	Hot water: district heating	
				1	4	96	96 180	1974		
Bronby Bronbryerne	B&S	Refractory wall Furnace RFHWG	H, C, LI	1	4	96	96	1971	Hot water: district heating	
Copenhagen Amager	Volund	Refractory wall Furnace Rotary kiln RFHGW	H, C, LI	3	12	288	864	1970	Hot water: district heating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
DENMARK (continued)										
Copenhagen West	Volund	Refractory wall Furnace Rotary kiln RFHGW	H, C, LI	3 1	12 14	288 336	864 336 1200	1970 1977	Hot water: district heating	
Ebeltoft	B&S Rasmussen	Refractory wall Furnace RFHWG	H, C, LI	1	1	24	24	1967	Hot water: district heating	
Frederica	Flynn & Emerich Rasmussen	Refractory wall Furnace RFHWG	H, C, LI	2	4.6	55	110	1966	Hot water: district heating	
Frederiksberg	Volund	Refractory wall Furnace Rotary kiln RFHWG	H, C, LI	2	6	144	288	1934	Hot water: district	Second Volund plant. Closed in 1974 after 40 years life
Frederikshavn	Brunn & Sorensen	Refractory wall Furnace	H, C, LI	1 1	3 4	72 96	72 96 168	1965 1971	Hot water: district heating	
Gentofte	Volund	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	2	6	144	288	1932	Steam: hot water	First Volund plant. Closed in 1974 after 40 years life
Haderslev	Volund	Refractory wall Furnace RFHWG	H, C, LI	1 1	3 4.5	72 108	72 108 180	1966 1975	Hot water: district heating	
Helsingor	Flynn & Emrick H,S&M	Refractory wall Furnace RFHWG	H, C, LI	1 1	4.5 6	108 144	108 144 252	1967 1975	Hot water: district heating	
Herning	B&S	Refractory wall Furnace RFHWG	H, C, LI	1 1 1	3 3 4	72 72 96	72 72 96 240	1963 1971 1973	Hot water: district heating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./Hr	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
DENMARK (continued)										
Hjorring	Volund	Refractory wall Furnace RFHWG	H, C, LI	1 1	2.5 4	60 96	60 96 156	1965 1977	Hot water: district heating	
Hoje Hojetastruj	B&S	Refractory wall Furnace RFHWG	H, C, LI	1	3	72	72	1967	Hot water: district heating	
Holstebro	B&S	Refractory wall Furnace RFHWG	H, C, LI	1 1	3 4	72 96	72 96 168	1970 1975	Hot water: district heating	
Horsens	B&S	Refractory wall Furnace RFHWG Rotary drum for sludge	H, C, LI Sewage sludge	1	6	144	144	1974	Hot water: district heating Flue gases: sludge drying	
Hoersholm	Volund		H, C, LI	2	3	72	144	1969	Hot water: district heating	
Kolding	B&S	Refractory wall Furnace RFHWG	H, C, LI	1 1	3 3	72 72	72 72 144	1969 1972	Hot water: district heating	
Korser	B&S	Refractory wall Furnace RFHWG	H, C, LI	1	2	48	48	1972	Hot water: district heating	
Middelfar	B&S	Refractory wall Furnace RFHWG	H, C, LI	1 1	2 2	48 48	48 48 96	1972 1975	Hot water is produced but not yet sold	
Nyborg	Von Roll	Water wall Furnace & Rotary kiln RFSG	Industrial	1	7.5	180	180	1975	Steam: District heating Electricity	Federal Industrial Waste Treatment Center

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
DENMARK (continued)										
Nyborg	B&S Destructor	Refractory wall Furnace RFHWG	H, C, LI	1 1	3 4	72 96	72 96 168	1970 1976	Hot water: district heating	
Odense Dalum	Volund	Refractory wall Furnace RFHWG	H, C, LI	1	2	48	48	1964	Hot water: district heating	
Ringsted	B&S Flynn & Emrich Rasmussen	Refractory wall Furnace RFHWG	H, C, LI	1	2	48	48	1969	Hot water: district heating	
Roskilde	Volund	Refractory wall Furnace RFHWG	H, C, LI	2	3	72	144	1966	Hot water: district heating	
Rudkobing	B&S Rasmussen	Refractory wall Furnace RFHWG	H, C, LI	1 1	8t/ 8 hr 8t/ 8 hr	8 8 8	8 8 16	1966 1971	Hot water: district heating	
Slagelse	B&S	Refractory wall Furnace RFHWG	H, C, LI	1	3	72	72	1971	Hot water: district heating	
Sonderborg	Volund	Refractory wall Furnace RFHWG	H, C, LI	1	3	72	72	1970	Hot water: district heating	
Sonderborg	B&S	Refractory wall Furnace RFHWG	H, C, LI	1	4	96	96	1973	Hot water: district heating	
Struer	B&S Destructor	Refractory wall Furnace RFHWG	H, C, LI	1	2	48	48	1967	Hot water: district heating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./Hr	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
DENMARK (continued)										
Svendborg	B&S Destructor	Refractory wall Furnace RFHWG	H, C, LI	1	3.5	84	84	1970	Hot water: district heating	
Svendborg	Volund	Refractory wall Furnace RFHWG	H, C, LI	1	4	96	96	1978	Hot water: district heating	
Taastrup	B&S Destructor	Refractory wall Furnace RFHWG	H, C, LI	1	3	72	72	1967	Hot water: district heating	
Tilst	B&S	Refractory wall Furnace RFHWG	H, C, LI	1	6t/ 8 hr	6	6	1968	Hot water: district heating	
Weston	B&S		Industrial waste	1	1	24	24	1974	Energy of which form?	
FINLAND										
Lahti	Lokomo			2	5	65	130	1967	Steam: 11.8t/hr/line for district heating	
Helsinki	Von Roll	Water wall Furnace RFSG	H, C, LI	2	8	200	400	1962	Steam: 15.8t/hr/line for district heating Hot water: internal Electricity	
Turku	Von Roll	Water wall Furnace RFSG	H, C, LI	2	5	120	240	1972	What is the heat recovery?	
FRANCE										
Agen	Von Roll INOR	Water wall Furnace RFSG	H, C, LI	1	3.1	75	75	1977	Need data	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity Lines	Rated Capacity Per Line M.T./Hr	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
FRANCE (continued)										
Angers	Von Roll INOR	Water wall Furnace RFSG	H, C, LI	2	5	120	240	1975	Steam: sale, internal	
Arles	Martin	Water wall Furnace	H, C, LI Sewage sludge	1	3.3	79	79	1977	Sewage sludge Destruction	
Armentieres	Volund(?) CEC			1 1	2 3	48 72	48 72 120	1939 1964	Heat recovery? Need data	
Arras	Von Roll INOR	Water wall Furnace RFSG		1	5	120	120	1976	Steam: internal	
Besancon	CEC		H, C, LI	1	4.17	100	100	1971	Heat recovery Need data	
Bezons-Argenteuil	Von Roll	Water wall Furnace RFSG		2	8.3	200	400	1975	Steam: internal use	
Biarritz Kleber Ave. Industrial Center	Unknown		H, C, LI	2	1	25	50	1925	Steam: heat public showers of industrial center	
Brive	Von Roll INOR	Water wall Furnace RFSG Thin-film Sludge dryer	H, C, LI Sewage sludge	2	2.5	60	120	1973	Steam: sludge drying	
Bruay en Artois	Von Roll(?)									
Deauville Trouville	Von Roll INOR	Water wall Furnace RFSG Thin-film Sludge dryer	H, C, LI Sewage sludge	2	2.5	60 30-40	120	1976	Steam Sludge drying and combustion	1 large dryer
Denain	Martin	Water wall Furnace	H, C, LI	2	5.51	132	265	1977	Sewage sludge Destruction	

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FRANCE (continued)										
Dieppe	Von Roll INOR Thermical	Water wall Furnace RFSG Thin-film Sludge dryer	H, C, LI	2	2.5	60 (72?)	120 (144?)	1971	Steam Sludge drying and combustion	2 smaller dryers
Dijon	Von Roll	Water wall Furnace	H, C, LI	2	11.6	278	557	1975	Steam: sale and internal Electricity	
Creil	Andco Torrax Caliqua	Vertical Shaft Pyrolysis Combuster	H, C, LI					1979		
Grasse	Andco Torrax	Vertical shaft Pyrolysis Incinerator	H, C, LI	1	5	120	120	1978	Steam: Perfume mfgr.	
Grenoble L'Ile d'Amour	VKW Tunzini	Rotary grate Water wall Furnace RFSG	H, C, LI	2 1	6.25 6.25	156 156	312 156 468	1972 1978	Steam: 3 x 18 t/hr 285 C, 33 Bar Steam: district heating	
Lillebonne	VKW Tunzini	Rotary kiln RFSG	Solid and pasty wastes Liquid wastes	1 1	3.5 2.4	84 58	84 58 142	1976 1976	Steam: 39 t/hr 285 C, 34 Bar	Solid and pasty wastes are injected in one kiln. Liquids are burned in a separate incinerator.
Lyon Gerland	Volund CEC	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	3 1	10 10	240 240	720 240 960	1963 1973	Steam: district heating	
Metz UIOM Chombiere	Martin CNIM	Water wall Furnace RFSG	H, C, LI	2	6	144	288	1970	Steam: 18 t/hr/line at 335 C, 16 Bar for district heating Electricity	

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FRANCE (continued)										
Mulhous Didenheim Usackers-Traeng	Von Roll INOR RFSG	Water wall Furnace	H, C, LI	2	5.4	130	260	1973		
Nancy	Heenan-Nichols Luchaire	Refractory wall Furnace RFSG	H, C, LI	1 1	6.5	125 125	125 125 250	1950 1975	Steam: sale	
Nice East	Martin CNIM	Water wall Furnace RFSG	H, C, LI	2	12	288	576	1977	Steam: 28.8 t/hr/line Electricity: 8.5 MW	
Paris Issy les Moulineaux	Martin CNIM TIRU	Water wall Furnace RFSG	H, C, LI	4	17	408	1632	1965	Steam: 40 t/hr/line Electricity: 24.9 MW Steam: 130 t/hr of back-pressure turbine steam for district heating	
Paris Ivry	Martin CNIM TIRU	Water wall Furnace RFSG	H, C, LI	2	50	1200	2400	1969	Steam: 134 t/hr/line Electricity: 64 MW Steam: 200 t/hr of back-pressure turbine steam for district heating	
Paris Romainville			H, C, LI						Converted to transfer station	
Paris St. Ouen	Volund C.E.C. TIRU	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	4	8.5 (6?)	204	816 (1200?)	1953 (1964?)	Hot water: district heating	
Rennes	Martin CNIM SOBREC	Water wall Furnace RFSG	H, C, LI	2	5	120	240	1969	Steam: 16.2 t/hr/line at 228 C, 27 Bar for district heating	
Rouen	Stein C.E.C.		H, C, LI	2	10.2	245	490	1967	Steam Electricity	
Rungis	VKW Tunzini	Water wall Furnace	H, C, LI	1	8	192	192	1968	Heat recovery(?)	

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FRANCE (continued)										
Saint Afrique Bournac	Shoppe SEPI			1	2	48	48	1972	Need data? Energy recovery	
St. Quentin	VKW Tunzini	Water wall Furnace	H, C, LI	1	8	192	192	1967	Need data? No energy recovery?	
Strasbourg	Von Roll INOR CPTD Siteco	Water wall Furnace RFSG	H, C, LI	3	12	288	864	1974	Steam: hot water District heating	
Tergnier	Alberti-Fonsar SOCEA		H, C, LI	2	8	192	384		Pilot plant for sludge drying	
Toulouse-le Mirail	VKW Tunzini	Rotary grate Water wall Furnace RFSG	H, C, LI	2 1	8 8	192 192	384 192 576	1970 1976	Steam: 21.7 t/hr/line at 250 C, 20 Bar Electricity District heating	
Toulouse-le Ramier	C.E.C.		H, C, LI	1	7			1936	No longer operating	

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				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
GERMANY										
Berlin-West Ruhleben	VKW & Durr-Borsig, now of VKW	Water wall Furnace RFSG	H, C, LI	4 2 2	16 16 16	384 384 384	1536 768 768 3072	1967 1969 1972	Steam: 25-32 t/hr/line 470 C, 72 Bar Electricity	
Berlin, Lichtenberg	VKW	Water wall Furnace RFSG	H, C, LI	2	15	360	720	1974	Steam: 32 t/hr/line 525 C, 111 Bar	Oil firing also
Braunschwis	IFB							1966		
Bobingen	Brule		Commercial waste	2	1	24	48	1975	Sludge drying	
Bonn-Bad Godesberg	Volund Koppers-Wistra	Refractory wall Furnace Rotary kiln RFSG	Industrial waste	2	10	210 132(?)	420 264(?)	1966	Steam: industry District heating	
Bremen Freie & Hansestadt	VKW Bremer-Vulcan Durr	Water wall Furnace RFSG	Industrial waste	3 1	15 20	360 480	1080 480 1560	1970 1977	Steam: 40 t/hr/line 220 C, 23 Bar Saturated District heating	Heating and air conditioning
Bremerhaven	Von Roll	Water wall Furnace RFSG	H, C, LI	3	10	240	720	1977	Steam: sale and internal District heating	
Cologne (Koln) Ford	Von Roll			1		100	100	1964	Energy recovered	
Cologne (Koln) Niehl Ford Werke	VKW	Refractory wall Furnace Traveling gate	Industrial waste	1	3.8	91	91	1972	Hot water: 42 GJ/hr 180 C, 13 Bar	
Cologne (Koln) Saarlouis Ford Werke	VKW	Refractory wall Furance Traveling gate	Industrial Solid waste	1	3	72	72	1978	Steam: 42 GJ/hr 191 C, 13 Bar Saturated	

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GERMANY (continued)										
Cologne (Koln) University Hospital	VKW Keller-Peukert		Hospital waste	2	2			1970	Steam: 8 t/hr/line 250 C, 24 Bar Central heating	
Darmstadt	Von Roll Mann Boiler	Water wall Furnace RFSG	H, C, LI	2 1	10 12	240 288	480 576 1056	1967 1973	Steam: District heating Electricity	Perhaps 200 T/D
Duesseldorf	VKW	Water wall Furnace RFSG	H, C, LI	1	10	240	240	1961	Steam: 12 t/hr at 360 C, 15 Bar Electricity	Closed. This was the original Duesse dorf grate experime
Duesseldorf	VKW Durr Boiler	Water wall Furnace RSG	H, C, LI	4 1	10 12.5	240 300	960 300 1260	1965 1972	Steam: 16 t/hr/line 50 C, 88 Bar Electricity District heating	
Duisberg Niederrheim	Von Roll(?) VKW(?)			3	22			1972	Steam Electricity District heating	Need verification
Eberbach	Skorstensbolaget							1971		
Essen Karnap	VKW Durr Boiler	Water wall Furnace Separate coal Furnace RFSG	H, C, LI	5	20	480	2400	1961- 1965	Steam: 130 t/hr/line 510 C, 98 Bar Electricity	Co-fired with coal
Ebingen	Lurgi							1962		
Eutin								1966		
Frankfurt	Andco Torrax Paul Wurth	Vertical Shaft Pyrolysis Combustor	H, C, LI	1	8.3	200	200	1978		
Frankfurt -am-Main I	Von Roll Baumgarte Boiler	Water wall Furnace RFSG	H, C, LI	2	12.5	300	600	1966	Steam: sale, internal Electricity	

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GERMANY (continued)										
Frankfurt -am-Main II	Von Roll Baumgarte Boiler	Water wall Furnace RFSG	H, C, LI	2	12.5	300	600	1967	Steam: sale, internal Electricity	
Freudenstadt Pino	VKW Keller Peukert		Vegetable waste	1	1.5			1962	Steam: 12 t/hr 450 C, 41 Bar Electricity	100% oil standby capability
Furth	Von Roll	Water wall Furnace RFSG	H, C, LI	1	3.3	80	80	1971	Steam to hot water District heating	
Furth Extension	Widmer & Ernst	Water wall Furnace RFSG	H, C, LI	1				1977		The additional lin required scrubbers on both
Fustenfeldbruck	Keller-Peukert		Industrial waste	1	6	144	144	1975		Sludge drying
Garmisch Parten-Kirchen	Koppers Wistra		H, C, LI							
Geiselbullach	Keller-Peukert		H, C, LI Sewage sludge	1	6	144	144	1975	Steam Sludge drying	
Gluckstadt	Claudius Peters		H, C, LI	1	2.5	60	60	1963		Closed in 1975 Sludge drying The only post WWII waste energy syste to have closed?
Goppingen	VKW		H, C, LI Industrial waste Waste oil	2	12	288	576	1975	Steam: 32 t/hr/line 410 C, 38 Bar Electricity District heating	
Gottingen Novopan	VKW Keller-Peukert		Wood waste	1	2			1961	Steam: 25 t/hr 66 Bar, saturated Hot water	
Haag						1230				
Hagen	VKW		H, C, LI	3	6	144	432	1967	Steam: 16 t/hr/line 194 C, 14 Bar Saturated Swimming bath	

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GERMANY (continued)										
Hamburg Rhorstrasse	Unknown	Refractory wall Furnace	H, C, LI					1896	Steam Electricity	Closed. Oldest kn commercial system converting municip solid waste to ene
Hamburg Borsigtrasse	Lurgi		H, C, LI							
Hamburg Billbrook	Von Roll Walther	Water wall Furnace RFSG	H, C, LI	2 3	8.3 8.3	200 200	400 600 1000	1959 1963	Steam Electricity District heating	
Hamburg Borsigstrasse	Martin	Water wall Furnace RFSG	H, C, LI	1 1	12 12	288 288	288 288 576	1967 1979	Steam: 27 t/hr 645 F, 270 psi Steam from new unit: 33.3 t/hr	
Hamburg Stellingerr-Moor	Martin Walther	Water wall Furnace RFSG	H, C, LI	2	19.5	590	1180	1973	Steam: 32-40 t/hr/line 770 F, 600 psi	
Hamburg Stapelfeld	Widmer & Ernst Steinmuller	Water wall Furnace RFSG	H, C, LI					1979		
Hameln	VKW	Water wall Furnace RFSG	H, C, LI	1	10	240	240	1977	Steam: 27.2 t/hr 450 C, 49 Bar Electricity	Added to existing power plant
Hals Chemical Works Harl	Von Roll	Rotary kiln	Industrial solids, slurries Waste oil	1		55	55	1966		
Hanover Continental	Von Roll			1		36	36	1964		
Ingolstadt	Widmer & Ernst	Water wall Furnace RFSG	H, C, LI Sewage sludge	2	7.5	180	360	1978	Sewage sludge destruction	
Iserlohn	VKW	Water wall Furnace RFSG	H, C, LI	2	16	384	768	1973	Steam: 50 t/hr 250 C, 17 Bar Electricity District heating	

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GERMANY (continued)										
Kampten-Allgau	Von Roll	Water wall Furnace	H, C, LI	1	4	96	96	1975	Steam	
Kassel	VKW Durr	Water wall Furnace RFSG	H, C, LI	1 1	10 10	240 240	240 240 480	1968 1969	Steam: 27.5 t/hr/line 450 C, 35 Bar Electricity	
Kempten I	Von Roll	Water wall Furnace RFSG	H, C, LI	1	4	96	96	1975	Steam: internal	
Kempten II	Von Roll	Water wall Furnace RFSG	H, C, LI	1	5	120	120	1976	Steam internal	
Kiel	VKW	Water wall Furnace RFSG	H, C, LI	2	5	120	240	1975	Steam: 16 t/hr/line 194 C, 14 Bar District heating	Combined with oil fired district heating plant buil in 1973
Kornwestheim	VKW Keller-Peukert	Refractory wall Furnace RFSG	Industrial waste	1	1.5			1967	Steam: 12 t/hr 450 C, 44 Bar	Co-fired with fuel oil
Krefeld	VKW	Water wall Furnace RFSG	H, C, LI Sewage sludge	2	12	288	576	1974	Steam: 38 t/hr/line 375 C, 25 Bar Electricity Sludge drying Industrial process steam	Suspension fired sludge
Landshut	Von Roll	Water wall Furnace RFSG	H, C, LI	1 1	3 3	72 72	72 72 144	1971 1974	Steam: sale and internal Electricity	
Landsweiler-Reden								1968		
Leverkeusen	Von Roll	Water wall Furnace Rotary kiln RFSG	Industrial waste	2	8.3	200	400	1970	Steam: internal Electricity District heating	
Leverkeusen	Kraus Maffei							1978		

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GERMANY (continued)										
Ludwigshafen BASF: I	Von Koll	Grate then Rotary kiln	Industrial waste	1	8.3	200	200	1960	Grate	Grate converted to liquid waste rotar kiln
Ludwigshafen BASF: II and III	Von Koll	Rotary kiln	Industrial waste	2	0.9	22	22	1964		
Ludwigshafen BASF	VKW	Rotary kiln Waste heat Boiler	Industrial solids, pastes and liquids	1 1	1.5 1.5	36 36	36 36 72	1969 1972	Steam: 13.5 t/hr 275 C, 23 Bar	
Ludwigshafen BASF	Krauss Maffei	Rotary kiln Waste heat Boiler	Industrial sludges, slurries, liquids	2	.84	20	40	1978	Steam: 14 t/hr 270 C, 25 atmos	76 kg/hr doughy material 765 kg/hr liquids
Ludwigshafen	Von Koll Baumgarte	Water wall Furnace Rotary kiln RFSG	H, C, LI	2	8.3	200	400	1967	Steam: internal Electricity Hot water: district heating	
Mainz-Mombach Nestle	VKW Keller-Peukert		Coffee and industrial waste	1	3.2			1964	Steam: 9 t/hr 25 Bar saturated	100% oil standby capability
Mannheim	KSG		H, C, LI Industrial waste Waste oil	2 1	12 20	288 420	576 420 996	1965 1973	Steam Electricity District heating	
Mannheim	Lambian	Water wall Furnace RFSG	H, C, LI Bark Industrial waste						Steam: 70 t/hr Electricity	
Munich North	Martin VKW Boiler	Water wall Furnace RFSG	H, C, LI	2 1	27.56 44.1	661 1058	1323 1058 2381	1964(I) 1966(II)	Steam: 41 t/hr/line 1005 F, 2675 psi Electricity District heating	Steam 60% coal Steam 80% coal
Munich South	Martin VKW Boiler	Water wall Furnace RFSG	H, C, LI	1 1	44.1 44.1	1058 1058	1058 1058 2116	1969(V) 1971(IV)	Steam: 41 t/hr/line 1005 F, 2675 psi Electricity District heating	Steam is 80% from natural gas and No. 2 fuel oil

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GERMANY (continued)										
Munich Messerschmidt	Keller Peukert Stepwise Sidewise grate		Paper Cardboard	1	0.5	12	12	1970	Hot water 160 C	
Munich	VKW									
Neckarsulm NSU (VW) Auto-Factory	VKW Keller-Peukert		Industrial waste	1	2.25			1965	Steam: 16 t/hr 450 C, 41 Bar Electricity	100% oil standby capability
Neufahrn VESO	Keller Peukert		H, C, LI	1	3	72	72	1970	Steam: 8 t/hr 208 C, 18 Bar District heating	
Neunkirchen	Martin	Water wall Furnace RFHWG	H, C, LI	1 1	5.5 10	132 240	132 240 372	1970 1978	Hot water 17.5 t/hr 360 F, 300 psi District heating	
Nurnberg (Nuremberg)	Von Roll	Water wall Furnace RFSG	H, C, LI	3	12.5	300	900	1968	Steam Electricity Hot water: internal District heating	
Nurnberg Extension	Martin	Water wall Furnace RFSG	H, C, LI	1	20	480	480	1980	Steam: 52.7 t/hr	
Neustadt Holstein	Maschinen Fabrik Essilingen									
Oberhausen	VKW	Water wall Furnace RFSG	H, C, LI	3	22	528	1584	1972	Steam: 50 t/hr/line 525 C, 69 Bar Electricity District heating	
Offenbach/Main	VKW	Water wall Furnace RFSG	H, C, LI	3	10	240	720	1969	Steam: 26 t/hr/line 260 C, 23 Bar Electricity District heating	
Radolfzell	VKW Keller-Peukert		Textile waste	1	0.5			1965	Steam 5 Bar saturated	

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GERMANY (continued)										
Rosenheim	VKW	Water wall Furnace RFSG	H, C, LI	1 1	4.5 6	108 144	108 144 252	1964 1969	Steam: 7.5 t/hr 194 C, 14 Bar saturated Steam: 12 t/hr 500 C, 59 Bar Electricity District heating	
Ruhr Project	Widmer & Ernst	Water wall Furnace	H, C, LI	2	15	360	720	1982	Waste destruction Electricity District heating	A most complex environmental and energy park
		Rotary kiln	Indus. chem. Waste oils Indus. solids	2				1982		
		Patholog. incin.	Patholog. waste	1	.35	8.4	8.4	1982		
Solingen	Von Koll	Water wall Furnace RFSG	H, C, LI	2	12.5	300 (200?)	600 (400?)	1969	Steam Electricity Hot water: sale and internal	
Stuttgart	VKW EUT Boiler	Water wall Furnace RFSG	H, C, LI	1 1	20 20	480 480	480 480 960	1965 1970	Steam: 125 t/hr 525 C, 64 Bar Electricity Distict heating	Co-firing with oil
Stuttgart (same plant as above)	Martin	Water wall Furnace RFSG	H, C, LI	1	20	480	480	1965	Steam: 50 t/hr 980 F, 940 psi Electricity District heating	75% of steam comes from fuel oil
				Stuttgart Plant Total			1440			
Russelsheim OPEL General Motors	Von Koll		Industrial Solid waste	1	2.5	60	60	1966	Energy recovered	
Wuppertal	VKW	Water wall Furnace RFSG	H, C, LI	4	15	360	1440	1975	Steam: 46 T/hr/line 350 C, 28 Bar Electricity	New scrubbers
Zirndorf	Von Koll Bunn Boiler			1	4	96	96	1971	Hot water District heating	

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HONG KONG										
Kennedy Town	Volund	Refractory wall Furnace Rotary kiln	H, C, LI	4 1	10.5 10.5	252 252	1008 252 1260	1967 1975	Steam (67) Hot water (75)	
Kwai Chung	Volund	Refractory wall Furnace Rotary kiln	H, C, LI	4	12.5	300	1200	1978	Steam	
Kowloon "A"	Volund	Refractory wall Furnace Rotary kiln	H, C, LI	4	10.5	252	1008	1968		
HUNGARY										
Budapest	VKW	Water wall Furnace RFSG	H, C, LI	4	15	360	1440	1980	Steam: 40 t/hr/line 445 C, 38 Bar Electricity	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
ITALY										
Bologna	Von Roll	Water wall Furnace RFSG	H, C, LI	3	8.3	200	600	1973	Steam	Listing shows 1966/70
Cattolica-Riccione	Von Roll	Water wall Furnace RFSG	H, C, LI	2	5	100	200	1975		
Cava Dei Terreni	De Bartolomeus D B Venien	Refractory wall Furnace	H, C, LI	2	1.6	38	77	1975	Steam	
Como	De Bartolomeus	Refractory Furnace	H, C, LI	1	4	96	96	1967		
Florence (Firenze)	De Bartolomeus	Refractory Furnace	H, C, LI					1974		
Forli	Von Roll	Water wall Furnace RFSG	H, C, LI	2	4.16	100	200	1977	Steam: internal	
Genoa	Von Roll	Water wall Furnace RFSG	H, C, LI	3	8.3	200	600	1972	Steam Electricity	
Leghorn (Livarno)	Von Roll	Water wall Furnace RFSG	H, C, LI	2	3.33	80	160	1973	Steam: internal	
Milan Old	Volund		H, C, LI	2	10	240	480	1938	Steam	
Milan I	Volund Safil	Refractory wall Furnace RFSG	H, C, LI	2	12.5	300	600	1968	Steam: 18 t/hr/line 440 C, 32 Bar Electricity: 6.25 MW	
Milan II	Volund Safil	Refractory wall Furnace	H, C, LI	2	12.5	300	600	1975		

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				Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
ITALY (continued)										
Milan III	Von Roll	Water wall Furnace	H, C, LI	3	12.5	300	900	1974		
Milan IV	Aerimpianti		H, C, LI	3	12.5	300	900	1979		
Milan Bruzzano (dupl?)	Volund Aerimpianti	Refractory wall Furnace RFSG	H, C, LI	3	14	336	1008	1977	Steam Electricity	
Milan Via Zama (dupl?)	Volund De Bartolomeus	Refractory wall Furnace RFSG	H, C, LI	2	10	240	480	1968	Steam: industry	
Milan Olgettina (dupl?)	Von Roll	Water wall Furnace	H, C, LI	3	12.5	300	900	1978	Steam Electricity Hot water: internal	
Milan Figino (dupl?)	De Bartolomeus		H, C, LI	2	6	144	288	1973	Steam Electricity	
Modena (?)	Von Roll	Water wall Furnace	H, C, LI	2	6	144	288	1978		
Padua	Alberti-Fonsar		H, C, LI	1 1	12 12	144 144	144 144 288	1961 ?	Steam Electricity	
Reggio Emilia	De Bartolomeus Volund Safil	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	2	4	96	192	1969	Steam District heating	
Rome Slia Sarr	Alberti-Fonsar		H, C, LI	2	4	96	192	1970	Steam	
Rome Sozain-Cecchini	Alberti-Fonsar		H, C, LI	6	4	96	576	1973	Steam Industry	
Rome	Alberti-Fonsar		H, C, LI				900	1969		
Savona	De Bartolomeus		H, C, LI	1	3	60	60		Need data	

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				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
ITALY (continued)										
Taranto	Von Roll	Water wall Furnace RFSG	H, C, LI	2	4	96	192	1973		
Terni	Von Roll	Water wall Furnace	H, C, LI	2	2.5	60	120	1975		
JAPAN										
Aizu-wakamatsu City Kanzashi-cho Aizu Area Minamiyongo 504 Sainokami	Mitsubishi Martin	Water wall Furnace RFSG	H, C, LI	1	9	216	216		Heating: internal	
Chiba Pref. Funabashi Higashimechi Plant 896	Kawasaki		H, C, LI	1	6.25	150	150		Hot water: internal	
Chiba Pref. Funabashi Nishuramachi Plant	Marubeni		H, C, LI	2	6.25	150	300	1972	Hot water: internal (very little energy)	
Chiba Pref. Shinminato Plant 225-24	Takuma		H, C, LI	3	6.25	150	450		Steam Electricity: internal	
Fukuoka City	Volund	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	2	12.5	300	600	1979	Steam	
Fukuoka City Eastern	Takuma		H, C, LI	2	12.5	300	600		Energy recovered	
Fukuoka City Western	Takuma		H, C, LI	3	6.25	150	450		Energy recovered	
Gifu City 6219-3 Rohdo Plant Okutamirohdo	Takuma		H, C, LI	2	6.25	150	300		Hot water: internal	

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JAPAN (continued)										
Hachinohe City	Volund	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	2	6.25	150	300	1979	Steam	
Hamamatsu City South 1715 Enoshima-cho	Kanson Kogyo K.K.		H, C, LI	1	7.5	180	180		Hot water: internal Swimming pool	
Himeji City Togo-cho 1450 Ohnawaba Ichikawa Plant	Takuma		H, C, LI	2	6.25	150	300		Hot water: internal	
Hiratsuka City 724 Ageo Plant	Toa Kogyo	Stationary		1	6.25	150	150		Hot water Public facilities	
Hitachi-Ota City 143 Masui-cho	Tokyo Tainetsu Sangyo	Batch Furnace	H, C, LI	2	6.25	300	600		Hot water Public facilities	
Ibaraki City 632 Nonomiya	Takuma	H-Type	H, C, LI	2	6.25	150	300		Hot water: internal	
Itami City 403 Yumi Iwaya	Marubeni		H, C, LI	3	9.38	225	675		Steam Electricity Hot water Internal	
Izumi City Abiko-Doyachinai Matsumori Sendai	Mitsubishi Heavy Industries		H, C, LI	1	6.25	150	150		Hot water Internal	
Kaizuko City 464 Handa Kishiwada	Kawasaki Heavy Industries		H, C, LI	3	6.25	150	450		Hot water Internal District heating	
Kamagaya 583-1 Nishibeppu	Yasuyuki Miake	M	H, C, LI	6	15	360	2160		Hot water Public facilities	
Kashiwa City Funato Plant 538	Takuma		H, C, LI	2	6.25	150	300		Heating: internal	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
JAPAN (continued)										
Kawaguchi City 3-16-1 Aoki	Kawasaki Heavy Industries		H, C, LI	2	6.25	150	300		Hot water Internal	
Kawaguchi City 290 Sotooh- numaderi Tsutsumi Tobeishinden	Nippon Kokan		H, C, LI	2	6.25	150	300		Hot water Internal Greenhouse	
Kawajachi City	Volund		H, C, LI	2	6.25	150	300	1976	Steam	
Kawasaki City Rinkai Plant 9 Chidori-cho	Mitsubishi Heavy Industries Martin		H, C, LI	3	8.33	200	600	1974	Steam: 23.5 t/hr/line Electricity: internal Hot water: internal	
Kawasaki City Ohzenji Plant 1285 Tama-ku	Mitsubishi Heavy Industries Martin		H, C, LI	3	6.25	150	450		Steam: industry Hot water: internal	
Kawasaki City Tsutsumine	Mitsubishi Heavy Industries Martin		H, C, LI	2						
Kawasaki City Tachibana Plant 1800 Shinsaku Takastu-ku			H, C, LI	3		200	600		Steam Electricity: internal Hot water: internal	
Kitakyushu City Kogasaki	Takuma		H, C, LI	3	8.33	200	600		Energy recovered	
Kitalyushu City Hiakari Kukuoka	Takuma		H, C, LI	3	6.25	150	450		Energy recovered	
Kobe City Karimojima Plant 3-12-28 Nagata-ku	VKW		H, C, LI	3 3	6.25 6.25	150 150	450 450 900	1973 1977	Steam: 6 t/hr/line (73) 214 C, 20 Bar saturated Hot water Swimming pools 45 t/hr/line (77)	
Kobe Higashi	Mitsubishi Heavy Industries Martin		H, C, LI	3	9.6	230	690	1975	Steam: 7 t/hr/line	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity			Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
					Per Line		Per System			
					M.T./ Hr	M.T./ Day	M.T./ Day			
JAPAN (continued										
?	Mitsubishi Heavy Industries Martin	Water wall Furnace RFSG	H, C, LI	3	6.3	150	450	1978	Steam: 4.2 t/hr/line	
Kyoto City North 27 Umegahanatakahana-cho Ukyo-ku	Marubeni Von Roll	Water wall Furnace RFSG	H, C, LI	2	8.33	200	400	1967	Hot water Internal	
Kyoto City	VKW	Water wall Furnace RFSG	H, C, LI	3	8.33	200	600		Steam: 27 t/hr/line 270 C, 19 Bar Electricity District heating	
Kyoto City West 26 Ohedakutsukake-cho Ukyo-ku	Takuma		H, C, LI	2	12.5	300	600		Hot water Internal	
Kyoto Minami II	Mitsubishi Heavy Industries Martin	Water wall Furnace RFSG	H, C, LI	3		200	600	1975	Steam: 27 t/hr/line	
Matsudo City	Volund	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	2	4.17	100	200	1980	Steam	
Mitsui Toatsu Chemical Inc.	VKW	Rotary kiln	Chemical waste	1	4.6	110	110	1975	Steam	
Nagareyama City Seimien Plant Kounosudai 1594-22	Sanki Engineering	Stationary Furnace							Hot water Public facilities	
Nagasaki	Mitsubishi Heavy Industries Martin	Water wall Furnace RFSG	H, C, LI	2	8.4	200	400	1978	Steam: 21.5 t/hr/line	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./Hr	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
JAPAN (continued)										
Nagoya City Inokoishi Plant 1334 Ohta Inokoishihara, Inotaka-cho Chikusa-ku	Takuma		H, C, LI	3		200	600		Hot water Internal	
Nagoya City Nanyo Aichi	Takuma		H, C, LI	3	12.5	300	900		Energy recovered	
Nagoya City Narumi Plant 90 Tenpaku Narumi-cho Midori-ku			H, C, LI	3	6.25	150	450		Hot water Internal Swimming pools	
Nagoya City East Owari Plant 33-1 Higashi Harugaoka-cho Owariasahi	Takuma		H, C, LI	2	6.25	150	300		Hot water Internal	
Niigata City Center 2108 Yanagiyama Haragasakishinden Tagami-cho	Sanki Engineering	Batch-Type	H, C, LI	6	12.5	300	1800		Heating: internal	
Niihama City	Volund	Grate furnace RFHWG	H, C, LI	3	3.12	75	225	1978	Hot water	
Niigata City West 2028 Shoshin	Niigata Jinpro		H, C, LI	2	6.25	150	300		Hot water: internal	
Nishinomiya City	Volund			3	6.25	150	450	1978	Steam	
Oita City No. 2	Takuma		H, C, LI	2	6.25	150	300		Energy recovered	
Okazaki City #1 Hachijo-cho 2-1 Tateshima	Takuma		H, C, LI	1		150	150		Hot water Internal	

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				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
JAPAN (continued)										
Okazaki City #2 Hachijo-cho 2-1 Tateshima	Takuma		H, C, LI	1	6.25	150	150		Hot water Internal	
Omiya City #3 52 Horaykita	Kawasaki Heavy Industries		H, C, LI	2	6.25	150	300		Hot water Internal	
Osaka Area Fukui Plant Kukuoka-ken Sakaigun Kandtsu-cho 32-1 Sasoka	Takuma		H, C, LI	2	6.25	150	300		Heating: internal	
Osaka Area Hachio City 7-1 Ageo-cho	Hitachi Shipbuilding		H, C, LI	4	6.25	150	600		Hot water: internal	
Osaka City Higashisumiyoshi Plant Urihasokuno-cho	Marubeni		H, C, LI	3	8.33	200	600		Hot water: internal	
Osaka City Higashiyodogawa-ku 2-134 Minamieguchi	Marubeni Von Roll		H, C, LI	3 (2?)	8.33 or	200 ([illegible])	600		Hot water: internal	
Osaka Area Hirakata City Hoyagawa Plant 654-1 Taguchi	Takuma	S.R.C. Type	H, C, LI	2	6.25	150	300		Hot water: internal	
Osaka City Jyoto				4	6.25	150	600			
Osaka Area Kakui Plant Habikino City 27 Kawamuko	Takuma		H, C, LI	2	6.25	150	300		Heating: internal	
Osaka Area Moriguchi City 2 Higashihashinami	Kawasaki Heavy Industries		H, C, LI	3	6.25	150	450		Hot water: internal	

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				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
JAPAN (continued)										
Osaka City Morinomiya Plant Joto-ku 1-6-11	Takuma		H, C, LI	3	12.5	300	900		Steam Electricity: sale Hot water: public facilities Hot water internal	
Osaka City Nishiyodo Plant 2-5-68 Owada	Von Roll		H, C, LI	2	8.33	200	400	1964	Steam Electricity: internal	
Osaka Area Sakai City #1 1-102 Ishihara-cho	Hitachi Shipbuilding		H, C, LI	2	6.25	150	300		Hot water: internal	
Osaka City Sumiyoshi Plant 1 Minamikagaya	Von Roll		H, C, LI	3	8.33	200	600		Hot water: internal (very little energy)	
Osaka City Suita City Northern	Takuma			1	7.5	180	180		Energy recovered	
Sagamihara	Mitsubishi Heavy Industries Martin	Water wall Furnace RFSG		3	8.36	200	600	1980	Steam: 21.5 t/hr/line	
Sapporo City No. 1 Hassamu Plant Hokkaido Nishi-ku 181 Hassamu	Takuma		H, C, LI	2	6.25	150	300		Hot water: internal Greenhouse Private office building Swimming pool Road heating	
Sapporo City No. 2 Atsubetsu Plant Siraishi-ku 3 Shimonopporo	Takuma		H, C, LI	2	12.5	300	600		Steam Electricity: internal Chilled water Air conditioning	
Shizuoka City Numagami Plant Minaminumagami 1273-1	Marubeni		H, C, LI	2	7.08	170	340	1974	Hot water: internal	

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JAPAN (continued)										
Takasaki City Wadatanaka-cho 610	Mitsubishi Heavy Industries		H, C, LI	2	6.25	150	300		Hot water: internal Public facilities	
Takatsuki City	Volund	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	3	6.25	150	450		Steam	
Takatsuki City Maejima 3-242-1	Mitsubishi Heavy Industries		H, C, LI	2		150	300		Hot water: internal	
Tama New Town	Von Roll		H, C, LI	2	6.25	150	300	1973		
Toba City Hajima Plant Haritsu-cho 3859	Kubota		H, C, LI	2		225	450		Hot water: internal Swimming pool	
Toda City Warabi Toda Plant Bijoki 978	Mitsubishi Heavy Industries		H, C, LI	2		150	300		Hot water: internal	
Tokayama Oil Cleaning Center	VKW	Rotary kiln	Special waste	1	1.38	33	33	1978	Steam: 6 t/hr 16 Bar saturated	
Tokyo Adachi-ku								1977	Steam Electricity 6.0 Mw	
Tokyo Chitose Setagaya-ku 1-1-1 Ohkura	Takuma		H, C, LI	2	12.5	300	600	1971	Steam Electricity: internal 1.7 Mw Hot water Public facilities	
Tokyo Chofu City Nimaibashi Plant Nomizu 2-1	Takuma		H, C, LI	2	6.25	150	300		Hot water: internal Public buildings	

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JAPAN (continued)										
Tokyo Area Ichikawa City Nishihama Plant 1003 Tajiri	Takuma		H, C, LI	3	6.25	150	450		Hot water: internal	
Tokyo Itabashi Plant Takashimadaira 9-48-1	Mitsui Takenaka Komtenk Volund		H, C, LI	4	12.5	300	1200	1974	Steam Electricity: internal 3.2 Mw Hot water Public facilities	
Tokyo Katsushika	Mitsubishi Heavy Industries		H, C, LI	3	21	500	1500	1976	Steam: 55 t/hr/line Electricity 12 Mw	
Tokyo Kita Plant Simokita-ku 1-2-36	Nippon Koppers		H, C, LI	2	12.5	300	600	1969	Hot water Public facilities (very little energy)	
Tokyo Kodaira City 2 Nakajima-cho	Sanki Engineering		H, C, LI	1 1 1	6.25 6.25 6.25	150 150 150	150 150 150 450		Hot water: internal	
Tokyo Koto Plant Koto-ku Shinsuna 3-Chome	Takuma Shimizu Constr.		H, C, LI	6	12.5	300	1800		Steam Electricity: internal Hot water Public facilities Swimming pool	
Tokyo Meguro								1981		
Tokyo Mitaka City Musashino Shinkawa 1-6-1	Sanki Engineering	Rotary drum	H, C, LI	2	6.25	150	300		Hot water: internal	
Tokyo Oi Plant Shinagawa-ku Higashi 5-Chome	Marubeni Von Roll Ohbayashi Gumi		H, C, LI	4	12.5	300	1200	1973	Steam Electricity: internal	

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JAPAN (continued)										
Tokyo Rusen-en Plant Higashi-Karume Shimosato 4-3-13	Ishikawajima-Harima Heavy Industries		H, C, LI	2	6.25	150	300		Hot water: internal	
Tokyo Rusen-en Plant Higashi-Karume Shimosato 4-3-10	Takuma		H, C, LI	1	6.25	150	150		Hot water: internal	
Tokyo Setagaya Plant Ohkura 1-1-1	Marubeni Von Roll		H, C, LI	3	12.5	300	900	1969	Steam Electricity: internal 2.5 Mw Hot water Public facilities	
Tokyo Shakujii Nerima-ku	Von Roll			2	12.5	300	600	1969	Steam Electricity 1.5 Mw	
Tokyo Shibuya-ku								1980		
Tokyo Shinjiku-ku								1979		
Tokyo Suginami Ward (dupl?)	Von Roll		H, C, LI	3		300	900	1967	Energy recovered	
Tokyo Suginami-ku								1978		
Tokyo Tama City Ochiai 2855	Marubeni		H, C, LI	2	6.25	150	300		Hot water: internal Public facilities	
Tokyo Tamagawa Plant Ota-ku Shimomaruko 2-33-1	Takuma		H, C, LI	2	12.5	300	600	1973	Steam Electricity 2.0 Mw	

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JAPAN (continued)										
Tomakomai City Itoi 401-4	Marubeni		H, C, LI	1	6.25	150	150		Hot water: internal	
Toyota Motor Co. Aichi			Industrial waste	1	2.42	58	58		Energy recovered	
Toyota City Togari Plant Daimyojin 39-3	Ebara Infilco		H, C, LI	4	12.5	300	1200		Hot water Public facilities	
Ueda City Sanada Plant Tenjin 3-11-31	Ebara Infilco		H, C, LI	3	7.5	180	540		Hot water Public buildings	
Utsunomiya City Yasaka Plant 330	Kawasaki Heavy Industries		H, C, LI	2	6.25	150	300		Hot water: internal Public facilities	
Urawa City Ohsaki Plant 317	Takuma		H, C, LI	2	6.25	150	300		Steam Electricity: sale	
Yokohama City Asahi Plant Shirane-cho 6-1	Mitsubishi Heavy Industries		H, C, LI	3	7.5	180	540		Hot water: internal Private office building Greenhouse	
Yokohama City Isogo Plant 38	Mitsubishi Heavy Industries		H, C, LI	3	6.25	150	450		Steam Electricity: sale Hot water: internal	
Yokohama City Tsurumi Yako 1-2-7	Mitsubishi Heavy Industries		H, C, LI	3	6.25	150	450		Hot water: internal Residences	
Yokohama Kohnan Plant Hino-cho 4449	Nippon Kokan Tohata Kenchiku Jimusho		H, C, LI	3	12.5	300	900	1974	Steam Electricity: internal Hot water Public facilities Swimming pool	

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JAPAN (continued)										
Yokohama City Minami-Totsuka Kamigo-cho 1570-1	Mitsubishi Heavy Industries Kashima		H, C, LI	3	20.83	500	1500	1976	Steam: 72.45 t/hr/line Electricity: internal Hot water: internal	
Yonezawa City Kasuga 4-1-20	Kanson-ro Kogyo			1	8.75	210	210		Hot water: internal Other uses	
LUXEMBORG										
Luxemborg	Martin SIDOR	Water wall Furnace RFSG	H, C, LI	2	8.3	200	400	1977	Steam: 25 t/hr/line Electricity	
Luxemborg	Andco Torrax Paul Wurth SIDOR	Vertical shaft Pyrolysis Incinerator	H, C, LI	1	8.3	200	200	1978	Pyrolysis gases Combustion gases Steam Electricity	First of four European Andco Torrax facilities Uses fuel oil
MONACO										
Monaco	Martin	Water wall Furnace	H, C, LI	2	5.82	140	280	1978	Steam: 12.7 t/hr/line	
NETHERLANDS										
Amsterdam	Martin	Water wall Furnace RFSG	H, C, LI	4	22	529	2116	1969	Steam: 46.5 t/hr/line	
Dordrecht	Martin GEVUDO		H, C, LI Sewage sludge	3	7.7	185	595	1972	Sludge drying	
Hague, The (Haag)	Von Roll Kunstler Modification	Water wall Furnace RFSG	H, C, LI	3 1	12.5 12.5	300 300	900 300 1200	1968 1974	Steam Electricity Hot water: internal	
Roosendaal	B&S	Refractory Furnace RFHWG	H, C, LI	2	8	96	192	1975	Hot water produced but not yet sold	

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NETHERLANDS (continued)										
Rotterdam	Martin	Water wall Furnace RFSG	H, C, LI	4	17.2	413	1654	1964	Steam: 33 t/hr/line 680 F, 412 psi	
Rotterdam Botlek	VKW RDM	Water wall Furnace RFSG	H, C, LI	6	20	480	2880	1972	Steam: 46 t/hr/line 360 C, 28 Bar Electricity District heating	
NORWAY										
Asane (?)				1	4t/8 hr		4	1971	Heat recovered	
Bergen I	B&S	Refractory wall Furnace	H, C, LI	1 1	2t/8 hr 2t/8 hr		2 2 4	1965 1968	Heat recovered	
Bergen II	B&S	Refractory wall Furnace	H, C, LI	1 1	4t/8 hr 2t/8 hr		4 2 6	1966 1968	Heat recovered	
Bergen III	B&S	Refractory wall Furnace	Industrial waste	1	1t/8 hr		1	1971	Heat recovered	
Drammen	B&S	Refractory wall Furnace	H, C, LI	1	4t/8 hr		4	1972	Heat recovered	
Kristiansand	B&S	Refractory wall Furnace	Industrial waste	1	2t/8 hr		2	1969	Heat recovered	
Oppegard	B&S	Refractory wall Furnace	H, C, LI	1	2t/8 hr		2	1968	Heat recovered	
Oslo	Esslingen E.M.F.	Refractory wall Furnace RFSG	H, C, LI	1		170	170	1966	Steam Electricity Industry	

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				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
NORWAY (continued)										
Oslo I	B&S	Refractory wall Furnace	H, C, LI	1	4t/8 hr 4t/8 hr		4 4 8	1966 1970	Heat recovered	
Oslo II	B&S	Refractory wall Furnace	H, C, LI	1 1	2t/8 hr 6t/8 hr		2 6 8	1968 1970	Heat recovered	
Oslo III	B&S	Refractory wall Furnace	Hospital waste	1	2t/8 hr		2	1966	Heat recovered	
Oslo IV	B&S	Refractory wall Furnace	Industrial waste	1	2t/8 hr		2	1966	Heat recovered	
Oslo V	B&S	Refractory wall Furnace	Industrial waste	1	2t/8 hr		2	1968	Heat recovered	
Oslo VI	B&S	Refractory wall Furnace	Industrial waste	1	3t/8 hr		3	1969	Heat recovered	
Trondheim I	B&S	Refractory wall Furnace	H, C, LI	1	4t/8 hr		4	1973	Heat recovered	
Trondheim II	B&S	Refractory wall Furnace	Industrial waste	1	2t/8 hr		2	1969	Heat recovered	
SINGAPORE										
Singapore	VKW	Water wall Furnace RFSG	H, C, LI	3	20	480	1440	1978	Steam: 32 t/hr/line 370 C, 35 Bar Electricity	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
SPAIN										
Barcelona I	Von Roll	Water wall Furnace RFSG	H, C, LI	2	12.5	300	600	1975	Steam Electricity	
Barcelona II	Von Roll	Water wall Furnace RFSG	H, C, LI	1	12.5	300	300	1975	Steam Electricity	
Moncada	Von Roll	Water wall Furnace RFSG	H, C, LI	1	5	60	60	1975	Steam	
Palma de Mallorca	Volund	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	1	8.25	198	198	1977	Steam	
SWEDEN										
Boras	Volund Landsverk	Refractory wall Furnace RFHWG	H, C, LI	2 1	2.5 4	60 96	120 96 216	1965 1972	Hot water District heating Electricity(?)	
Borlange	Plibrico P.E.M.	Refractory wall Furnace RFHWG	H, C, LI	2	2	48	96	1963	Hot water District heating	
Gavle Tierp	B&S		Hospital waste	1	1	24	24	1973	Heat recovered (which kind?)	
Gothenburg Frolunda	Plibrico P.E.M.	Refractory wall Furnace RFHWG	H, C, LI	1	4	96	96	1962	Hot water District heating	
Gothenbrug Savenas	Von Roll	Water wall Furnace RFSG	H, C, LI	3	12.5	300	900	1972	Steam: 42.7 t/hr/line Hot water District heating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
SWEDEN (continued)										
Halmstad	Martin	Water wall Furnace RFSG	H, C, LI	2	5.5	132	264	1971	Need data (?)	Martin says no stea District heat mag. says steam
Koping	Landsverk	Refractory wall Furnace RFHWG	H, C, LI Hospital waste	2	5	120	240	1972	Hot water Hospital heating	
Linkoping	Volund Landsverk	Refractory wall Furnace RFSG	H, C, LI	2	2.5	60	120	1958	Steam Electricity District heating	
Linkoping	Von Roll	Water wall Furnace RFSG	H, C, LI	1	5	120	120	1966	Steam Electricity District heating	
Lovata	B&S	Refractory wall Furnace RF hot air Generator	H, C, LI Sewage sludge	2	9	216	432	1968	Sewage sludge drying	Consumes non-dewatered digested sewage sludge
Lulea	B&S	Refractory wall Furnace RF hot air Generator	H, C, LI Sewage sludge	2	7.5	180	360	1967	Sewage sludge drying	
Lulea	Volund Landsverk	Refractory wall Furnace RFHWG	H, C, LI	2	5	120	240	1969	Hot water District heating	
Malma Spillepeng	Martin Tabougnar	Water wall Furnace RFHWG	Commercial and industrial waste	2	8.52	205	410	1973	Hot water: 320 F, 142 psi District heating	One source claims sludge drying (?)
Sadra Sotenas	B&S	Refractory wall Furnace	H, C, LI	1	2	48	48	1971	Heat recovered	Where is this located? Not on ma

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
SWEDEN (continued)										
Skovde	B&S		Hospital waste	1	1	24	24	1971	Hot water Hospital heating	
Stockholm	Pilbrico	Refractory wall Furnace RFHWG	H, C, LI	2	1	24	48	1975	Hot water District heating	
Stockholm Bollmora	Von Roll	Water wall Furnace RFHWG	H, C, LI	2	4.15	100 (120?)	200 (240?)	1968	Hot water District heating	
Stockholm Bredang	Destructor Norba	Refractory wall Furnace RFHWG	H, C, LI	1	3	72	72	1965	Hot water District heating	
Stockholm Hogdalen	VKW	Water wall Furnace RFSG	H, C, LI	2	15	360	720	1970	Steam Electricity	
Stockholm Huddinge	Destructor Norba	Refractory wall Furnace RFHWG	H, C, LI Hospital waste	1	4	96	96	1971	Hot water Hospital heating	
Stockholm Solna	Destructor Norba	Refractory wall RFHWG	H, C, LI	3	4	96	288	1967	Hot water District heating	
Stockholm Solna	B&S	Refractory wall Furnace	H, C, LI	1 1	4 4	96 96	96 96 192	1973 1974	Heat recovery	Rebuilt units
Stockholm Sundbyberg	Volund Landsverk	Refractory wall Furnace RFHWG	H, C, LI	2	2.5	60	120	1954	Hot water District heating	
Stockholm Taby	Pilbrico P.E.H.	Refractory wall Furnace RFHWG	H, C, LI Hospital waste	1	3	72	72	1960	Hot water Hospital heating District heating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
					Per Line		Per System			
				Lines	M.T./ Hr	M.T./ Day	M.T./ Day			
SWEDEN (continued)										
Sundsvall	Volund	Refractory wall Furnace RFSG	Bark	2	17.5	420	840	1978	Steam: industry	
Trollhattan	B&S Norba	Refractory wall Furnace RFHWG	H, C, LI	1	3.5	84	84	1974 (1969?)	Hot water District heating	
Umea	Von Roll	Water wall Furnace RFHWG	H, C, LI	1 (2?)	5	120 (100?)	120 (200?)	1970	Hot water District heating	
Uppsala	Volund Landsverk	Refractory wall Furnace RFSG	H, C, LI	2 1	2.5 3	60 72	120 72 192	1962 1965	Steam District heating	
Uppsala (same plant as above)	B&S	Refractory wall Furnace RFSG	H, C, LI	1	5	120	120	1971	Steam District heating	
				Uppsala Facility Total			312			

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
SWITZERLAND										
Basel I	Von Roll Volund	Refractory wall Furnace Rotary kiln	H, C, LI	2	8	200	400	1943	Hot water District heating Industrial uses	
Basel II	Von Roll	Water wall Furnace	H, C, LI	2	12.5	300	600	1969	Steam Industrial heating Electricity District heating	
Basel Ciba-Geigy	VKW	Rotary kiln	(1) Animal carcasses		0.3	7.2	7.2	1973	Steam: 3.5 t/hr Saturated 14 Bar	
			(2) and other liquid waste		0.3	7.2	7.2 14.4	1973		
Beringen	Von Roll	Water wall Furnace	H, C, LI Waste oil Emulsions Tank bottoms Sludge	2	2.5	60	120		Hot water Internal	Buehler/Dano compost rejects
Bern I	Von Roll	Water wall Furnace RFSG	H, C, LI	2	4.15	100	200	1954	Steam Electricity Industial process steam Hot water District heating	The world's first integrated water t wall refuse fired steam generator
Bern II	Von Roll	Water wall Furnace RFSG	H, C, LI	2	10	240	480	1975 (1972?)	Steam Electricity Industrial process steam Hot water District heating	
Bienne	Von Roll	Water wall Furnace		1	2.5	60	60	1968	Steam	
Buchs SG II Werdenberg- Liechtenstein	Widmer & Ernst Alberti- Fonsar	Water wall Furnace RFSG	H, C, LI	1	5	120	120	1975	Steam Electricity Industrial process steam Hot water District heating	Buchs I was a simp refuse burner now converted to a pathological incinerator
Bulach	Lurgi		H, C, LI Sewage sludge	2	2.25	54	108	1969	Sludge drying	Lurgi had many refuse to energy plants prior to WW

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./ Hr	Rated Capacity Per Line M.T./ Day	Rated Capacity Per System M.T./ Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
SWITZERLAND (continued)										
Cazis/Unterrealta	Ufag K&K Ofenbau		Waste oil Emulsions Sludge	1	1	24	24	1971	Hot water Internal	
Colombier Neuchatel	Widmer & Ernst Alberti- Fonsar	Water wall Furnace RFSG	H, C, LI	2	5	100	200	1971	Steam Electricity 7,756 MWh in 1975	
Geneva Cheneviers I	Von Roll	Water wall Furnace RFSG	H, C, LI	2	8.3	200	400	1966	Steam Electricity Hot water	
Geneva Cheneviers II	Martin	Water wall Furnace RFSG	H, C, LI	1	19.15	460	460	1979	Steam: 54 t/hr Electricity	Low temperature s from Krauss/Maffe superheated in t Martin RFSG
Geneva Cheneviers II	Krauss/Maffei		Industrial waste	1						Low temperature s from Krauss/Maffe superheated in t Martin RFSG
Graubunden Cazis Unterrealta	Ufag K&K Offenbau		H, C, LI	1	1.7	41	41	1971	Heat recovered: internal	
Hinwil Kezo Oberland Zweckuerbund Zurcher	Martin Sulzer	Water wall Furnace RFSG	H, C, LI	1 2	5 6.26	120 150	120 300 420	1970 1976	Steam: 12.5 t/hr/line 755 F at 600 psi Electricity 2.34 MW 14,600 MWh in 1975	
Horgen	Ufag K&K Ofenbau	Refractory wall Furnace	H, C, LI (non-combustible material)	1	3.33	80	80		Heating: internal	A Buehler/Dano compost plant wit an incinerator/wa heat boiler for non-compostable material
Kirchberg Bazenheid	Martin	Water wall Furnace RFSG	H, C, LI	2	3.5	84	168	1976	Steam: 14.7 t/hr/line Industry	
La Chaux de Fonds	CEC		Industrial oils, chemicals sludges, biocides	2	3	72	144	1972		

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
SWITZERLAND (continued)										
Lausanne	Von Roll			2	4.15	100	200	1958	Steam Electricity Hot water	
Limmattal Dietikon	Martin Sulzer	Water wall Furnace RFSG	H, C, LI	2	2.3	55	110	1971	Steam: 3.5 t/hr/line 770 F, 526 psi Electricity 1.4	
Locarno	De Bartolomeis	Refractory wall Furnace RFHWG	H, C, LI	2		50	100		Hot water Industry	
Luzern (Lucerne)	Von Roll	Water wall Furnace RFSG	H, C, LI	2		100	200	1971	Steam Electricity	
Handorf	Von Roll	Water wall Furnace RFSG	H, C, LI Industrial waste	1	1	24	24		Hot water	Buehler/Dano compost rejects
Mouthey	De Bartolomeis	Refractory wall Furnace	H, C, LI	2		180	360		Steam Electricity	
Olten	OFAG			1 1		100 50	100 50	1964	Heating	Buehler/Dano compost rejects
Schaffhouse	Von Roll			2		60	120	1970	Energy recovery	
Turgi Baden-Brugg	Widmer & Ernst Alberti-Fonsar	Water wall Furnace RFSG	H, C, LI Waste oil	2	4.15	100	200	1970	Steam Electricity Heat sewage treatment and hazardous waste treatment plants	
Upper Thurgan Region Toggenburg	Von Roll			1		72	72	1968	Energy recovery	
Uzwil	Nichols		Industrial slurries and sludges	1		72	72		Heat for drying sludges and slurries	Buehler compostin

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./Hr	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
SWITZERLAND (continued)										
Winterthur	Von Roll	Water wall Furnace RFSG	H, C, LI	2		100	200	1965	Steam Electricity District heating Industry	
Winterthur	Martin	Water wall Furnace RFSG	H, C, LI	1	16.7	400	400	1978	Steam Electricity District heating Industry	
					Winterthur Plant Total			600		
Yverdon	Unitherm		H, C, LI	2		72	144		Energy recovered	
Zuchwil Solothurn Emmenspitz	Von Roll	Water wall Furnace RFSG	H, C, LI Waste oils	2		240	480	1976	Steam Electricity	
Zurich Hagenholz Line #1, #2	Von Roll		H, C, LI	2		200 (260?)	400 (520?)	1969	Steam Electricity District heating	
Zurich Hagenholz Line #3	Martin		H, C, LI	1	18.73	474	474	1973	Steam: 38 t/hr/line 788 F, 540 psi Electricity: 2 x 5.25 MW District heating	
Zurich Josefstrassse	Horsfall- Destructor		H, C, LI	2	3.8			1904	Steam Electricity District heating	
Zurich Josefstrasse	Heenan- Froud	Water wall Furnace RFSG	H, C, LI					(1928?)	Steam Electricity Distarict heating	
Zurich Josefstrasse	Martin	Water wall Furnace	H, C, LI	1		511	511	1978	Steam: 44.8 t/hr/line Electricity District heating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity Lines	Rated Capacity Per Line M.T./Hr	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
UNITED KINGDOM										
Coventry	Martin	Water wall Furnace RFSG	H, C, LI	3	12	288	864	1974	Steam: 44 t/hr/line 208 C, 18.5 Bar Electricity: internal Hot water: industrial space heating	
Jersey Island	Martin Birwelco Bronswerk Boiler	Water wall Furnace RFSG	H, C, LI	1 1	4.5 6	108 144	108 144 252	1978 1978	Steam: 15.6 t/hr Steam: 19 t/hr 400 C, 40 Bar Electricity	
Linwood	VKW	Water wall Furnace RFSG	H, C, LI	2	8	192	384	1974	Hot water: internal	
London Edmonton	VKW	Water wall Furnace RFSG	H, C, LI	5	14	336	1680	1971	Steam: 39.5 t/hr/line 455 C, 43 Bar Electricity	
Mansfield	B&S	Refractory wall Furnace	H, C, LI	1	5.5	132	132	1972	Energy is prepared but not sold. What kind?	
Middleton	VKW	Water wall Furnace RFHWG	H, C, LI	1	8	192	192	1979	Hot water: internal	
Nottingham	Martin	Water wall Furnace RFSG	H, C, LI	2	11.7	281	562	1973	Steam: 24 t/hr/line 700 F, 412 psi Electricity: 2 x 1.5 MW Hot water District heating	
Otley/Ilkey near Leeds	B&S	Refractory wall Furnace RFHWG	H, C, LI	1	3.25	78	78	1973	Hot water District heating (not yet connected?)	
Sheffield Bernard Road	VKW	Water wall Furnace RFSG	H, C, LI	2	10	240	480	1975	Steam: 25 t/hr/line Saturated, 20 Bar Electricity District heating	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
UNITED KINGDOM (continued)										
South Yorkshire		RDF								
West Sussex		RDF								
West Midlands		RDF								
Imperial Metal Industries		RDF								
Wiltshire		RDF								
Blue Circle		RDF								

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
U.S.A.										
Akron, Ohio	B&W Claus, Pyle Schomer, Burns & De Haven Teledyne	Water wall Suspension Fire furnace Burns RDF – Primary fuel RFSG	H, C, LI				900	1980	Steam: district heating and cooling Industrial process steam Ferrous	
Albany, New York	Smith & Mahoney	Water wall Suspension Fire furnace Burns RDF – Primary fuel RFSG	H, C, LI				675	1981	RDF - Fluff Steam: district heating and cooling State office bldgs. Ferrous	
Amarillo, Texas	Affiliated						240	1965	Steam	
Ames, Iowa	Hennisgson Durham & Richardson	Water wall Suspension Fire furnace Burns RDF – Co-fires with coal RFSG	H, C, LI				180	1975	RDF Steam Electricity Ferrous Aluminum	
Andrews Air Force Base Washington, D.C.		Modular package incinerator/ Heat exchanger								Under constructi
Atlanta I Georgia	Volund International Incinerators Inc.	Refractory wall Furnace Rotary kiln	H, C, LI	4	6.5	156	624	1943	Steam	Closed
Azusa, California		Pipelines with nega- tive pressure in landfill	H, C, LI					1978	Methane	
Baltimore, Maryland (City)	Monsanto U.S. EPA	Landgard Rotary kiln Pyrolysis	H, C, LI				800	1975	Steam District heating Ferrous	Monsanto is now d. associated with u Should start com- busting (not pyrol zing) in 1979

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
U.S.A. (continued)										
Baltimore, Maryland (County) Cockeysville	Teledyne Maryland Environmental Services	RDF Prepared	H, C, LI				550	1978	RDF not being sold yet Ferrous Aluminum Glass	Demonstration pla RDF now landfille
Blytheville, Arkansas	Consumat	Modular package Incinerator/ Heat exchanger	H, C, LI				45	1975	Steam: saturated	Light industrial customer
Braintree, Massachusetts	Riley Stoker/ Boiler	Water wall Furnace RFSG	H, C, LI	2		120	240	1971	Steam Industrial	Industrial customer
Bridgeport, Connecticut United Illuminating Plant Devon Plant	Occidental Petro Combustion Equipment Assoc.	RDF–powder Co-fire	H, C, LI	2	33.75	810	1620	1979	RDF - Dust Steam Electricity	Eco Fuel II
Briggs-Stratton Plant, Michigan										
Buffalo, Orchard Park, New York	Andco Torrax Carborundum U.S. EPA	Vertical shaft	H, C, LI	1			180	1972	Low Btu gas was produced but not sold	Major demonstrati closed in 1975
Central Contra Costa County Concord, California	Envirotech	Multiple Hearth Furnace Pyrolysis RDF	H, C, LI Sewage sludge						Sludge destruction	Major demonstrati
Charleston, So. West Virginia	Union Carbide	Vertical shaft Pyrolysis Combustion	H, C, LI	1	7.5	180	180	1974	Gas: 300 Btu/cu.ft.	Major demonstrat Has operated for periods up to 90
Chicago, Illinois								1877		Steam used to oper City of Chicago I water pumps

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity			Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
					Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
U.S.A. (continued)										
Chicago, S.W. Illinois Stickney	Volund International Incinerators Inc. Waste Managemt.	Refractory wall Furnace Rotary kiln RFSG	H, C, LI	2	10.5	252	504 (1,200?)	1959 (1963?)	Steam Industrial uses	Closed
Chicago, S.W. Illinois Crawford Plant Commonwealth Edisor	Ralph Parsons Consoer Townsend	RDF	H, C, LI				900	1978	RDF - Fluff Steam Electricity	Commonwealth Edis is the single customer
Chicago, N.W. Illinois	Martin IBW (now owned by U.O.P.)	Water wall Furnace RFSG	H, C, LI	4	15	360	1440	1971	Steam	Steam will soon b sold to Brachs Ca
Cockeysville, Maryland							550	1976	RDF	Major demonstrati
Columbus, Ohio	Battelle U.S. EPA	Water wall Suspension Fire furnace Burned RDF	H, C, LI				200	1975	Steam Electricity	Major demonstrat using high sulfu coal to combat corrosion caused chlorides
Columbus, Ohio	Babcock & Wilcox	Water wall Suspension Fire furnace Burned RDF	H, C, LI	6	7.5	180	1080	1981	Steam Electricity	Progress is challenged by th Ohio Power Siti Commission
Crossett, Arkansaas	Zurn Industries	Modular Package Incinerator/ Heat Exchanger	Bark						Steam Heating and air conditioning	Georgia Pacific
Crossville, Tennessee	Farrier Smokatrol	Modular Package Incinerator Boiler	Industrial solid waste Rubber trimmings	2			54	1979	Steam: saturated	Rubber Co.

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
U.S.A. (continued)										
Dade County Miami, Florida	Parsons & Whittemore Black-Clawson	Hydropulper	H, C, LI				2700	1980	Steam Electricity 475 GW/year Ferrous Aluminum Glass	
Detroit, Michigan	Combustion Engineering Waste Resources Inc.	Water wall Suspension Fire furnace Burns RDF RFSG	H, C, LI				3000	1982	Steam sold to Detroit Edison Electricity	May still be negotiating
DiNard, Oregon Roseburg Lumber Co.	Babcock & Wilcox		Bark				1080		Steam: 68 t/hr	
Dubuque, Iowa John Deere Plant										
Duluth, Minnesota	Copeland (now Envirotech)	Fluidized bed Burns RDF	H, C, LI Sewage sludge				360 306	1979	RDF Steam: internal heating and air conditioning	Sludge has 30% dry solids
East Bridgewater, Connecticut (near Brockton)	CEA	Front-end Separation	H, C, LI				600	1979	Eco-Fuel II Steam: Industrial uses	
Eugene, Oregon			Bark					196?	Steam District heating	Experiments were ducted with hous- hold, commercial industrial waste
Flint, Michigan General Motors		RDF into Modified Water wall Furnace RFSG	Light industrial waste					1975	Steam Industrial	
Fort Detrick U.S. Army Maryland		Modular package Incinerator 1 Boiler	Army Base waste					1979	Steam	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
U.S.A. (continued)										
Fort Lauderdale, Florida	Detroit Stoker	Refractory wall Furnace RFSG	H, C, LI				450	1966	Steam	Closed
Fort Smith, Arkansas		Modular package Incinerator 1 Boiler	Industrial waste						Steam Hot water Space heating	
Franklin, Ohio	Black Clawson U.S. EPA	Hydropulper Fluid bed	H, C, LI Sewage sludge	1	5.6	135	135	1971	Heat produced is not fully recovered. Pulp produced is sent to Asphalt Roofing Plant. Destruction of sludge Ferrous Aluminum Glass Fiber	Major demonstrati First plant model for Hempsted and Dade County. 45 T/D is actuall processed. May close in 1979.
Genesee County Flint, Michigan	Consumat	Modular package Incinerator/ Heat Exchanger		2		50	100	1980		
Groveton, New Hampshire	Environmental Control Products	Modular package Incinerator/ Boiler	H, C, LI (1 day/week) Bark Sawdust 4-1/2 days/week Paper scraps				27	1975	Steam	
Hampton, Langley AFB Virginia	J.H. Kenith	Mass Burning RFSG					180	1980	Steam	NASA Langley A.F. Bas
Harrisburg, Pennsylvania	Martin IBW (now owned by U.O.P.)	Water wall Furnace RFSG	H, C, LI Sewage sludge	2	15	360	720	1972	Steam Heating and air conditioning	Steam line from refuse burning pl to Penn Power & Li district heating station soon completed. Sludge system under construction in 1969.

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day			
U.S.A. (continued)										
Hempstead, New York	Flynn & Emerick	Refractory wall Furnace RFSG	H, C, LI Sewage sludge				700	1952	Steam Electricity	Closed
Hempstead, New York	Black Clawson Parsons & Whittemore	Hydropulper RDF into air-swept spout spreader hog fuel stokers	H, C, LI				1800	1979	Wet pulp RDF Steam Electricity Ferrous Glass Aluminum	Hydrasposal TM
Jackson, Michigan Goodyear Tire & Rubber	Lucas American		Tires	1			36	1974	Steam Rubber Tire Mfgr.	Problems in startup. Need inf
Jacksonville, Naval Air Station Florida		RDF Modular package Auger Incinerator 1 Boiler	Navy Base waste	2	.83	20	40			
Kennewich, Washington	Battelle Northwest Laboratories							1971		Demonstration Closed
Lane County, Eugene, University of Oregon	Allis Chalmers Western Waste Corp.	RDF Water wall Suspension Fire furnace RFSG	H, C, LI Bark				450	1979	RDF - Fluff Energy recovery(?)	
Lewisburg, Tennessee	CICO	Modular package Incinerator 1 Heat exch.	H, C, LI				54			
Los Angeles, L.A. County Sanitation District Palos Verdes California	Reserve synthetic fuels (was NRG Nufuel)	Piping with negative pressure in landfill	H, C, LI					1974	Methane recovery 300 Btu/cu.ft. Cleaned gases sent to natural gas pipeline	Major demonstrati 2 million cu. ft. of gas/day. Enoug for 3,500 homes.

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity				Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
				Lines	Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
U.S.A. (continued)										
Los Angeles, Hollywood		Piping with negative pressure in landfill	H, C, LI					1974	Methane recovery	Major demonstratio
Los Angeles, California Sheldon-Arleta Landfill		Piping with negative pressure in landfill						1979	Methane recovery One billion cu. ft. per year	
Madison, Wisconsin Madison Gas & Electric	H.L. Smith	RDF Water wall Suspension Fire furnace RFSG	H, C, LI				360	1979	Steam Electricity	Nominally processe 180 T/D
Marysville, Ohio Rockwell Intl.	Kelley	Modular package incin./ Heat exch.	Factory waste Corn stalks							
Mayport, Florida Navy Base		Modular package incinerator/ Heat exchanger								
Menlo Park, California	Combustion Power Corp. CPU-400	Fluidized bed Gas turbo generator	H, C, LI				400	1971	Hot combustion air Electricity	Major demonstrat Closed and converted to coal experiments
[illegible], New York		Refractory wall Furnace RFSG	H, C, LI	4		135	540	1952	Steam: Internal	Retrofitted in 1977
Miami, Florida		Refractory wall Furnace	H, C, LI				900	1956	Steam Electricity Hospital heating	Closed
Milwaukee, Wisconsin South Creek Plant Wisconsin Electric	Americology Bechtel	RDF burned Water wall Suspension Fire furnace RFSG	H, C, LI	2	30	720	1440	1978	RDF - Fluff Steam Electricity	Wisconsin Electric burns the RDF

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./ Hr	 M.T./ Day	 Per System M.T./ Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
U.S.A. (continued)										
Monroe County Rochester, New York Rochester Gas & Electric, Plant #7	Raytheon	RDF burned Water wall Suspension Fire furnace RFSG	H, C, LI				1800	1979	RDF - Fluff Steam Electricity	In shakedown during 1979
Mountainview, California		Piping with nega- tive pressure in landfill	H, C, LI					1975	Methane gas	Major demonstation
Nashville, Tennesse	Babcock & Wilcox Detroit Stoker Carrier I.C. Thomasson	Water wall Furnace RFSG Chiller Station	H, C, LI	2	15	360 477	720 954	1974	Steam Chilled water District heating and cooling	Energy is sold at $5.50 - $6.00 per 1000 pounds.
Newark, New Jersey	Combustion Equipment Associates Occidental	RDF System	H, C, LI	2	37.5	900	1800	1982	Eco Fuel II	Rating increased 360 shot tons to metric tons in 19
New Orleans, Louisiana	National Center for Resource Recovery	RDF System					650	1978	RDF (now landfilled) Ferrous Aluminum Glass	Major demonstrati
New York 47th St.										Closed
New York Williamsburg Bridge	Unknown	Refractory wall Furnace	H, C, LI					1906	Steam Electricity	Electricity lit Williamsburg bri Closed
New York Staten Island	Unknown	Refractory wall Furnace	H, C, LI					before 1910	Steam Electricity	Closed
Niagra Falls, New York Hooker Chemical	Foster Wheeler	RDF Water wall Suspension Fire furnace RFSG	H, C, LI				1980	1980	Steam: 660,000 lb/hr Electricity	Chemical processe will receive energ

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity			Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
					Per Line M.T./ Hr	Per Line M.T./ Day	Per System M.T./ Day			
U.S.A. (continued)										
Norfolk, Virginia Sewells Point U.S. Navy Base	Foster Wheeler	Water wall Furnace RFSG	Navy Base Waste Wood Cardboard Oil Soaked	2	6.25	180	360	1967	Steam Saturated	Used in ships at port; 10% of total base steam
Norfolk, U.S. Navy			H, C, LI Coal	3			2000	1982	Steam Electricity	Coal for standby and peaking
Northeastern Massachusetts North Andover Haverhill Massachusetts	Martin UOP	Water wall Furnace RFSG	H, C, LI				3000	1982	Steam Electricity	
North Little Rock, Arkansas	Consumat	Modular Package Incinerator 1 Boiler	H, C, LI Wood waste Railroad Tie ends	4			90	1977	Steam Industry	Creosoting plant
Oceanside, New York	Flynn & Emerick	Refractory wall Furnace Waste heat Boiler Retrofited	H, C, LI	2 1		270 150	540 150 690	1965	Steam Electricity: internal	Retrofitted with waste heat boiler 1974 by Charles Velzey Assoc.
Pepeekeo, Hawaii	Babcock & Wilcox		Bagasse				1700	1972	Steam Electric	Need info.
Pinnelas County Clearwater St. Petersburg Florida Power Florida	Martin UOP	Water wall Furnace RFSG	H, C, LI				1800	1983	Steam Electricity 40 MW 500 kW /ton refuse	
Pompano Beach, Florida	Waste Manage- ment U.S. DOE	RDF Anaerobic digestion	H, C, LI Sewage sludge				100	1979	Methane	Anaerobic digestio
Pontiac, Michigan		RDF Existing							Steam	

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Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Rated Capacity Lines	Per Line M.T./Hr	Per Line M.T./Day	Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
U.S.A. (continued)										
Providence, Rhode Island	Widmer & Ernst	Refractory wall Furnace	H, C, LI					1983	Energy recovery	In final negotiati
Redwood City Pacific G&E	Pyrosol	Pyrolysis		2	2	50	100	1979	Pyrolysis gas Electricity 1.667 MW/hr	
Rochester, New York							180	1970		Kodak
Salem, Virginia	Consumat	Modular Package Incinerator/ Boilers		4	.95	23	91	1979	Steam: 20,000 lb/hr	Mohawk Rubber buy steam
San Diego, California	Occidental Research (formerly Garrett Research) U.S. EPA	RDF Flash Pyrolysis	H, C, LI				180	1978	RDF Pyrolytic oil Pyrolysis gas Char Ferrous Aluminum	Major demonstrati Closed after 1 ye
Saugus, Massachusetts (near Boston)	Von Roll Wheelabrator- Frye De Matteo Bros. Resco	Water wall Furnace RFSG	H, C, LI	2	22.5	540	1080	1975	Steam: 50 t/hr/line 845 F Electricity	GE is the custome
Siloam Springs, Arkansas	Consumat	Modular Package Incinerator/ Boiler	H, C, LI	1	17/12 hrs		17	1975	Steam: 30 million lbs/yr Industrial	Food cannery
St. Louis, Missouri	Combustion Engineering. Union Electric Horner & Shifrin U.S. EPA	RDF Water wall Suspension Fire furnace RFSG	H, C, LI						RDF Ferrous Steam Electricity	Major demonstrati Closed in 1976 Model for many other systems

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./ Hr	Rated Capacity Per Line M.T./ Day	Per System M.T./ Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
U.S.A. (continued)										
Tacoma, Washington	Boeing	RDF					455	1979	Steam	
Watertown, Wisconsin Wis-Pak Pepsi Cola	Kelley	Modular package Pyrolysis Incinerator Boiler	Wood pallets Cardboard Scrap wood Paper containers	1					Steam Hot water	6 million Btu/hr bottle cleaning an 3 million Btu/hr heating = 9 millio Btu/hr total
Wilmington, Delaware	Raytheon U.S. EPA Del. S.W. Auth	RDF Aerobic digestion	H, C, LI Sewage sludge				1000 50	1982	RDF Steam Compost Ferrous Aluminum Glass	Major demonstratio
York, Pennsylvania Danskin Sportswear	Kelley	Modular package Pyrolysis Incinerator Boiler		1					Steam Space heating Heat set and pressing	

Location City, State Plant Name	System Mfgr. Grate or Boiler Vendor, Designer	Plant Type	Kind of Waste	Lines	Rated Capacity Per Line M.T./Hr	Rated Capacity Per Line M.T./Day	Rated Capacity Per System M.T./Day	Date Begin Operation	Form, Uses and Details of Resources Recovered	Comments and Status
USSR										
Charkow	VKW	Water wall Furnace RFSG		3	15	360	1080	1982	Steam: 45 t/hr/line 250 C, 13.5 Bar District heating	
Moscow	Martin ?	Water wall Furnace RFSG		2	8.4	200	400	1975	Steam District heating	
Moscow	Alberti- Fonsar F.O.S.			2	4	96	192		Steam District heating	
Moscow	Volund	Refractory wall Furnace Rotary kiln RFSG		4	12.5	300	1200	1978	Steam District heating	
Pjatigorsk	VKW	Water wall Furnace RFSG		3	15	360	1080	1982	Steam: 45 t/hr/line 250 C, 13.5 Bar District heating	
Yalta	VKW	Water wall Furnace RFSG		3	15	360	1080	1981	Steam: 45 t/hr/line 250 C, 13.5 Bar District heating	

DESCRIPTION OF COMMUNITIES VISITED

General Comments About the Communities

Background information about the communities visited is necessary for better understanding of historical solid waste practices, system development, energy utilization, system performance, etc. Chapters on these subjects follow this section.

In this section, each community is described in terms of its waste generation areas, terrain, natural and manmade boundaries, relationship among neighboring communities, population, and key employment activities that influence waste composition.

Collection Areas and Jurisdictions

The collection areas and radii are shown in Table C-1. Note that Werdenberg-Liechtenstein has the greatest area and longest radius. Yet this plant has the smallest capacity at 120 tonnes per day. Conversely the largest capacity plant, Paris:Issy, has the smallest collection area and radius.

Numbers of separate jurisdictions associated with each plant are also shown in the table. A point to be observed is that, in most of these systems, it is necessary to obtain waste from many jurisdictions to improve economics of scale.

Terrain, Natural and Manmade Boundaries, Neighborhoods

The sampling of plants covers the many geographical conditions to be found in Europe. Table C-2 is a collection of phrases regarding terrain, natural boundaries, highways, railroads, neighborhoods, etc.

Population

Population numbers must be treated carefully with respect to definition. Table C-3 provides four kinds of numbers where applicable:

- Metropolitan area
- Key city
- Host city if different than the key city
- Waste shed area served

The most relevant figure for plant designers is the waste shed area served. Population numbers range from 48,000 in Dieppe to 837,286 in Duesseldorf. These figures do not experience the extremes of the other earlier columns. This, naturally, is due to economics, of scale required. At the low end, the plant must be big enough to achieve some degree of efficiency to pay for fixed costs. However at the high end, costs of transporting refuse limit the maximum population served in a waste shed.

It is significant to note that the waste may be collected from only a portion of the metropolitan area (as in Dusseldorf) or from far beyond the metropolitan area (as in Baden-Brugg and Dieppe).At three of the plants, the community is not even considered to be a metropolitan area. Other metropolitan area populations range from 40,000 people in and around Dieppe, France to the 9,150,000 population of greater Paris.

TABLE C-1. COLLECTION AREA AND RADIUS

Trip	City	Area		Thous.	Collection Radius		Separate Jurisdictions
		km^2	$miles^2$	Acres	km	miles	Number
1	Werdenberg-Liechtenstein, Switzerland	900	345	22	33	20	28
2	Baden-Brugg, Switzerland	100	38	24	--	--	56
3	Duesseldorf, W. Germany	--	--	--	--	--	32
4	Wuppertal, W. Germany	100	38	24	--	--	--
5	Krefeld, W. Germany	--	--	--	--	--	--
6	Paris:Issy, France	--	--	--	--	--	55(a)
7	Hamburg:Stellinger-Moor, W. Germany	--	--	--	--	--	--
8	Zurich:Hagenholz, Switzerland	--	--	--	--	--	--
9	The Hague, The Netherlands	--	--	--	15	9.3	--
10	Dieppe, France	--	--	--	12	7	--
11	Gothenburg, Sweden	1,000	386	247	--	--	9
12	Uppsala, Sweden	--	--	--	--	--	7
13	Horsens, Denmark	--	--	--	--	--	--
14	Copenhagen:Amager, Denmark	--	--	--	--	--	--
15	Copenhagen:West, Denmark	--	--	--	--	--	12

(a) Sending waste to four large refuse plants.

TABLE C-2. TERRAIN, NATURAL BOUNDARIES, HIGHWAYS, NEIGHBORHOODS

Trip	City	Descriptives, Comments
1	Werdenberg-Liechtenstein	Plant in valley, surrounded by mountains, Rhine River, small town
2	Baden-Brugg	Plant in valley, surrounded by hills, Limatt River, railroad, highway
3	Duesseldorf	Plant in flat industrial area, few houses
4	Wuppertal	Plant on top of large hill, deep valley nearby
5	Krefeld	Plant on flat Rhine flood plain, few large industries nearby
6	Paris:Issy	Plant on bank of Seine River, railroad on other side, residential neighborhood
7	Hamburg:Stellinger-Moor	Plant on flat industrial area near major highways
8	Zurich-Hagenholz	Plant on last plot of flat industrial land close to city
9	The Hague	Plant on flat land in middle of residential neighborhood
10	Dieppe	Plant in shallow valley, seashore resort
11	Gothenburg	Plant in shallow valley, industrial area surrounded by homes
12	Uppsala	Plant on glaciated flat land away from the town
13	Horsens	Plant on seacoast near downtown
14	Copenhagen:Amager	Plant on edge of man-made island, ship access on both sides
15	Copenhagen:West	Plant on flat land at highway intersection

TABLE C-3. POPULATION OF VISITED AREAS

Trip		Population (Number of People)				
		Metropolitan Area(a)	Key City(a)	Host City Number (If Different)	Host City Name (If Different)	Waste Shed Area Served
1	Werdenberg-Liechtenstein		8,570		Buchs	76,685
2	Baden-Brugg	66,800	13,700		Baden	140,000
3	Duesseldorf	1,150,000	675,437			837,286
4	Wuppertal	920,000	412,403			444,000
5	Krefeld	5,350,000(b)	231,642			350,000 (refuse) 600,000 (sludge)
6	Paris:Issy	9,150,000	2,299,830	47,561	Issy les Moulineaux	
7	Hamburg:Stellinger-Moor	2,250,000	1,733,802		Stellingen	500,000
8	Zurich:Hagenholz	775,000	383,000		Hagenholz	560,000
9	The Hague	800,000	471,137			550,000
10	Dieppe	40,000	25,822			48,000(c)
11	Gothenburg	665,000	444,651		Partille	670,000
12	Uppsala		138,116			
13	Horsens		53,966			64,000
14	Copenhagen:Amager	1,505,000	545,350		Amager	620,000
15	Copenhagen:West	1,505,000	545,350	26,345	Herlev	620,000

(a) Source: 1978 Commercial Atlas and Marketing Guide, Rand McNally & Co.
(b) Metropolitan area of Essen.
(c) Population increases in the summer, so that 48,000 is a year-around average.

Key city populations range from 8,570 in Buchs, Switzerland to 2,299,830 in Paris. The several plants located in suburbs of the key city have their populations shown as well. Effective populations are seasonably higher in Werdenberg, The Hague, and Dieppe due to the influx of vacationers. In fact, at Dieppe and nearby Deauville, the population increases by a factor of 5. Thus the plant had to be designed for the very high (200,000 people) summer load in Deauville.

Specific Comments About the Communities

Werdenberg-Liechtenstein (Buchs, Switzerland)

This relatively new and colorful plant named Werdenberg-Liechtenstein is located on the Werdenberger Binnenkanal (Inland Canal) paralleling the Rhine River on the border between eastern Switzerland and Liechtenstein. (See Figure C-1.) Actually the plant is located in the city of Buchs, Switzerland. The name "Werdenberg" comes from a very small neighborhood that is at the inside edge of Buchs. The region's area is roughly 900 square kilometers (345.3 square miles).

The setting and terrain are most picturesque. The plant is set on the flat bottoms of the Rhine Valley and nestled between snow capped mountains. (See Figure C-2). Being so close to the canal did present foundation problems and additional costs were incurred as is discussed later in the plant architecture section.

Buchs itself had a 1970 census population of 8,570 while the total waste generating region had 76,685 inhabitants. After the Swiss referendum in 1975 loosely labeled, "Swiss for the Swiss", the population declined as Mediterranean workers returned to their native lands. The population in 1977 is likely equal to or less than the 1970 figures.

The community population is somewhat seasonal with more people during the winter skiing and summer vacation seasons.

The government and industry employment sectors are stable with respect to growth.

In this region of two countries and 28 cities, there are 18 Switzerland and 15 Liechtenstein counties. All of the Swiss counties are within the Canton (state) of St. Gallen.

The industrial base is varied with the following composition:

- International headquarters for Hilti fastening systems (metal and explosives) (in the past, Hilti sent sintered magnesium pellets to the plant.)
- Hovel household boilers
- Textile manufacturers (trimmings)
- Carpet manufacturers (trimmings).

Baden-Brugg (Switzerland)

As shown in Figure C-3, the plant is located in a narrow valley. The Limmatt River is on one side and a 2-track electric railroad is immediately against the other side of the plant. There are a few residences to the west but no concentrated landuse in the immediate vicinity. The population served is about 140,000.

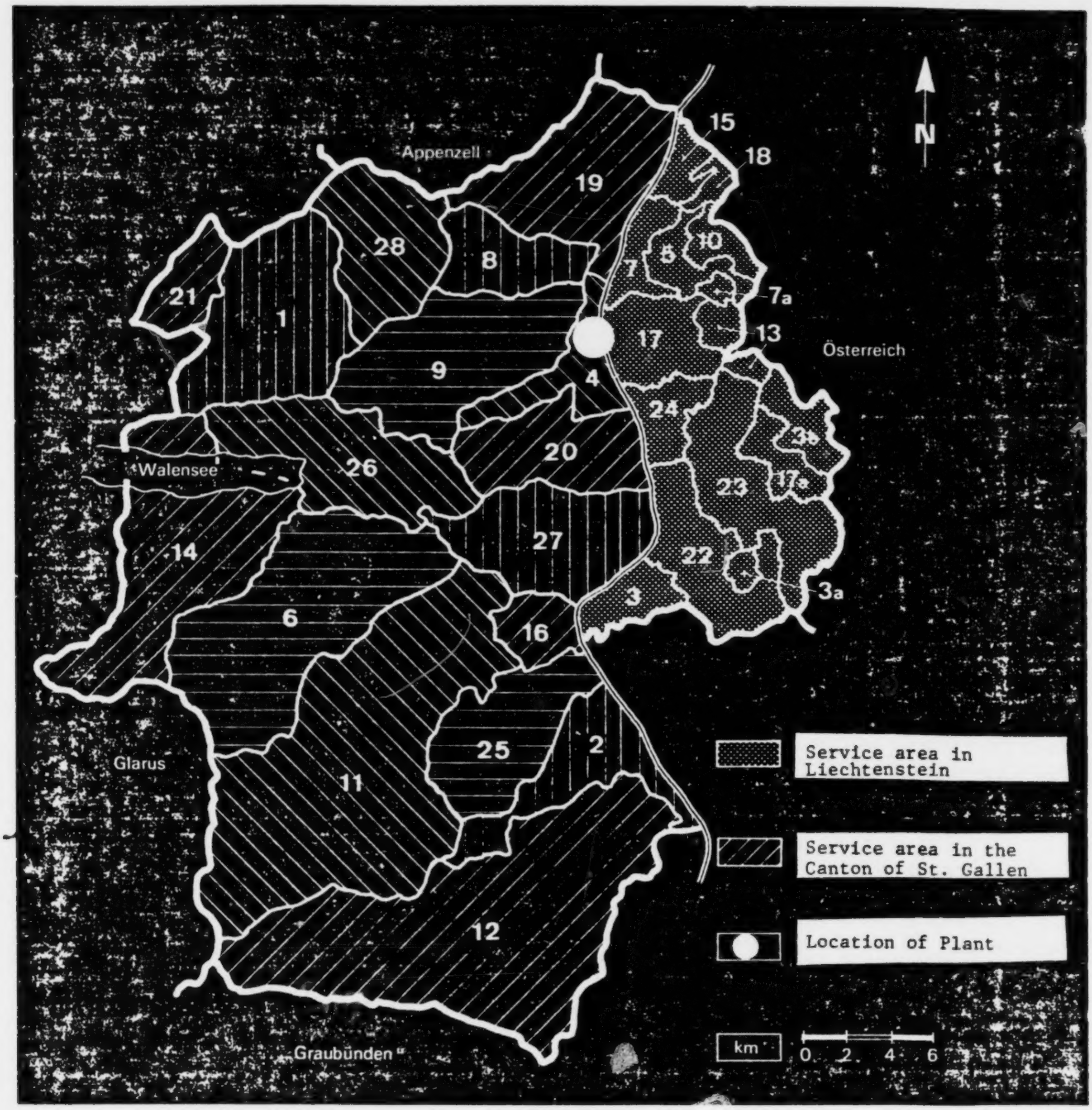
15
18
Appenzell
19
28
8
10
5
7
7a
21
1
13
17
Österreich
9
4
24
3b
20
26
Walensee
23
17a
27
14
22
3
3a
6
16
25
2
Glarus
11
12
Graubünden
N
Service area in Liechtenstein
Service area in the Canton of St. Gallen
Location of Plant
km
0
2
4
6

FIGURE C-1. REFUSE GENERATION AREA SHOWING THE SERVICE AREAS IN THE CANTON OF ST. GALLEN AND IN LIECHTENSTEIN.
Werdenberg-Liechtenstein Plant Courtesy of Widmer + Ernst (Alberti-Fonsar)

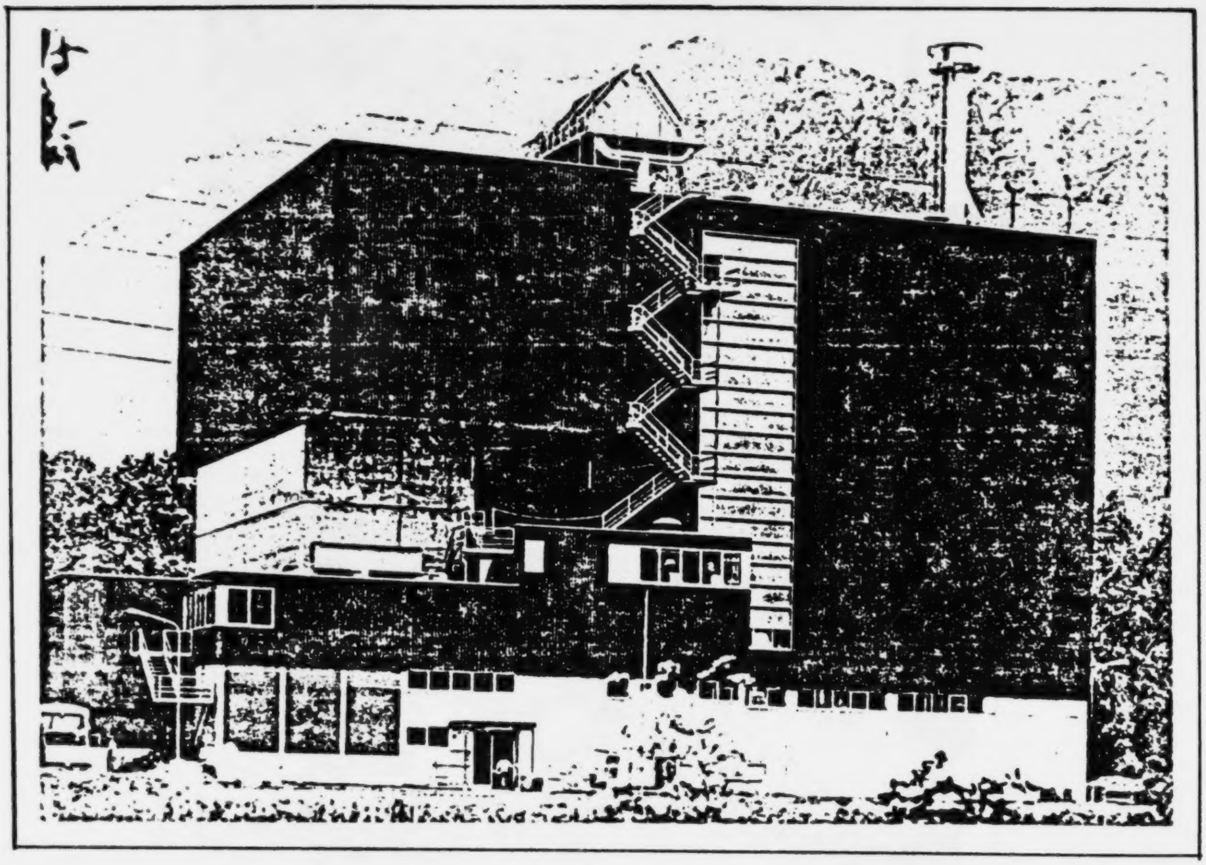

FIGURE C-2. PROFILE OF PLANT SURROUNDED BY MOUNTAINS
Werdenberg-Liechtenstein Plant
(Courtesy of Widmer + Ernst (Alberti-Fonsar))

FIGURE C-3. VIEW OF BADEN-BRUGG 200 TONNE PER DAY PLANT FROM THE ADJACENT SEWAGE TREATMENT PLANT PROPERTY (Courtesy Baden-Brugg Waste Management Association)

A sewage treatment plant is located just North of the plant. Then just South of the plant, a privately operated hazardous waste treatment plant, named Fairtec, processes chemical wastes (arsenic, etc.) from all of Northern Switzerland. This is yet another example of the "Sanitary Park" so prevalent in Europe.

The area served (see Figure C-4) is approximately 100 sq km (259 sq. mi.), about 18 km (29 mi) long and 5.5 km (9 mi) wide. There are 56 villages in the area. About 12 of these comprise original members of the Association, 44 other communities participate by sening waste.

Many industrial plants are located in the area served by this plant. The world headquarters of the Brown-Boveri Co., is in Baden very near to the plant. The engineering-construction firm of Motor-Columbus is also in Baden.

Duesseldorf (West Germany)

Duesseldorf is a densely populated, highly industrialized city of about 600,000 people located on the very busy Rhine River. The terrain is very flat and many smaller industrial cities are located nearby along the river. Land costs are very high.

Duesseldorf is a major industrial center and river port with a broad variety of manufacturing activities. See Figure C-5.

Wuppertal (West Germany)

The area of Wuppertal-Remscheid, Figure C-6, is extremely hilly. It has an area of approximately 100 km^2 (259 mi^2), the center of which is about 28 km (17.5 mi) north east of Duesseldorf. Population density is approximately 5440 people/km^2 (2100 people/mi^2). Manufacturing is the predominant employment activity in the area.

In 1929, the city of Wuppertal had been formed by the combination of two cities in the narrow valley (tal) of the Wupper River--Barmen, population 187,000 and Elberfeld, population 112,000. The area of Barmen stretches along 4 mi (6.5 km) of the Wupper. High wooded hills surround it.

At Barmen in 1907, the first municipal incinerator in Germany was built. It operated for about 40 years.

Barmen, which became part of Wuppertal in 1929, was one of the most important manufacturing centers of Germany early in the century. Ribbon weaving was the chief industry; chemicals, buttons, rugs, and pianos were also made.

Krefeld (West Germany)

The flat surroundings of the plant shown in Figure   are typical of the terrain in the Krefeld area which is a highly industralized community located about 30 km (20 mi) northwest of Duesseldorf. As is also evident in Figure C-7, there is no densely populated area in the immediate vicinity of the plant--only an occasional factory.

The plant receives considerable amounts of industrial waste. Most of the potential energy in the household and industrial waste is used to drive off moisture in the community's sewage sludge prior to combustion of the sludge.

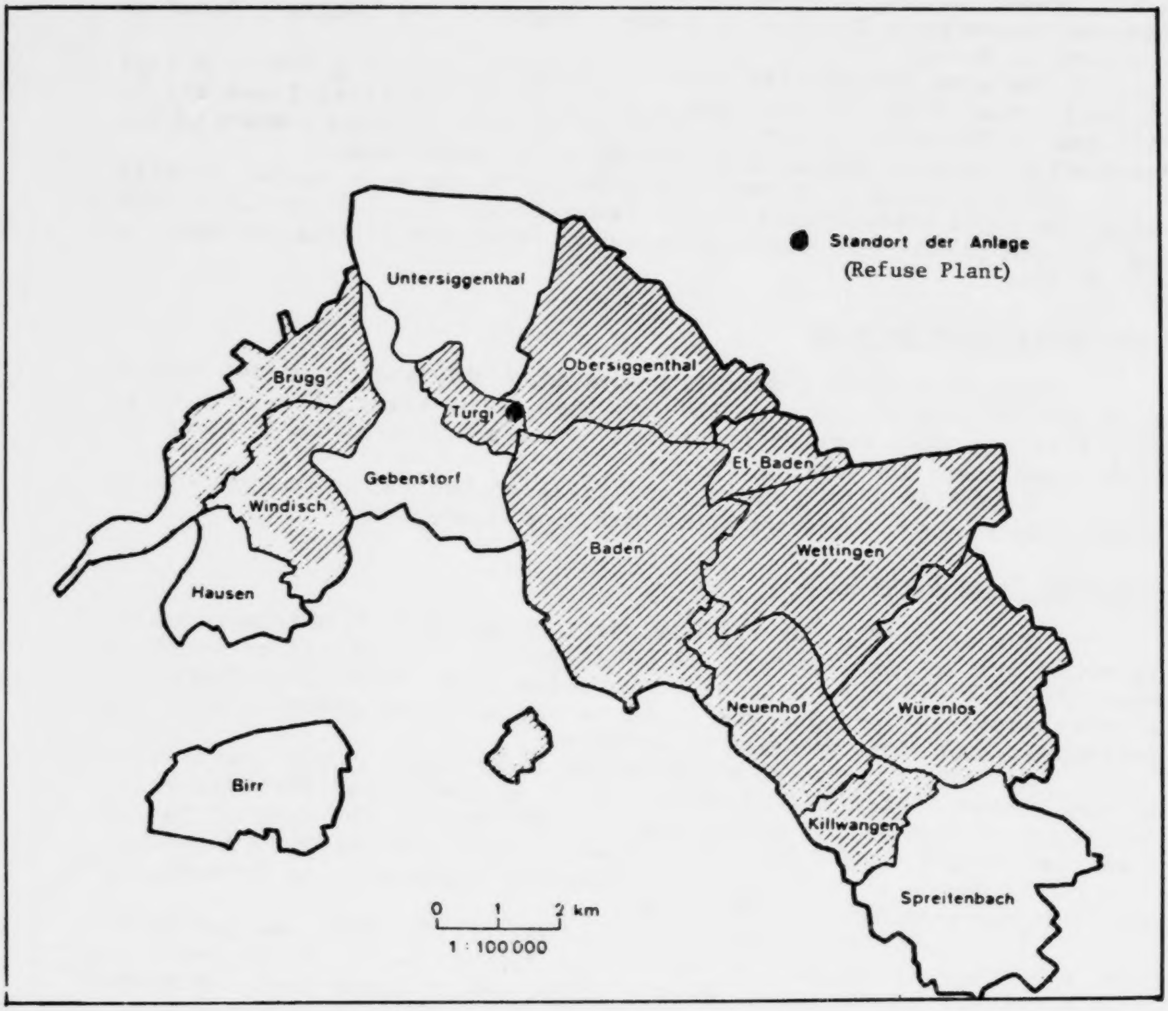
● Standort der Anlage
(Refuse Plant)
Untersiggenthal
Obersiggenthal
Brugg
Turgi
Gebenstorf
Windisch
Hausen
Baden
Et-Baden
Wettingen
Neuenhof
Würenlos
Killwangen
Spreitenbach
Birr
0 1 2 km
1 : 100 000

FIGURE C-4. AREA IN AARGAU CANTON SERVED BY BADEN BRUGG PLANT

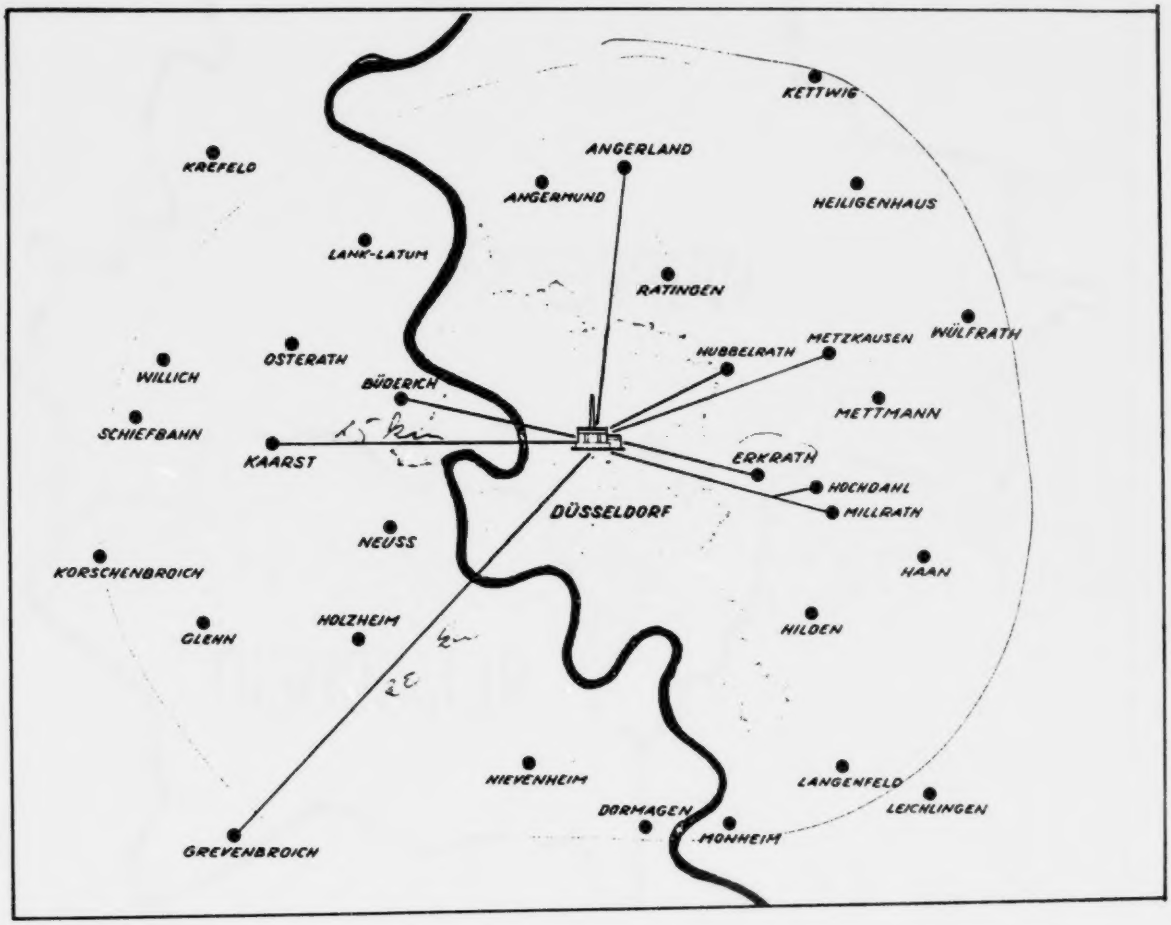
KETTWIG
ANGERLAND
KREFELD
ANGERMUND
HEILIGENHAUS
LANK-LATUM
RATINGEN
WÜLFRATH
METZKAUSEN
HUBBELRATH
OSTERATH
WILLICH
BÜDERICH
METTMANN
SCHIEFBAHN
15 km
KAARST
ERKRATH
HOCHDAHL
MILLRATH
DÜSSELDORF
NEUSS
HAAN
KORSCHENBROICH
HILDEN
HOLZHEIM
GLENN
NIEVENHEIM
LANGENFELD
LEICHLINGEN
DORMAGEN
MONHEIM
GREVENBROICH

FIGURE C-5. WASTE COLLECTION AREA SERVED BY DUESSELDORF PLANT(1)

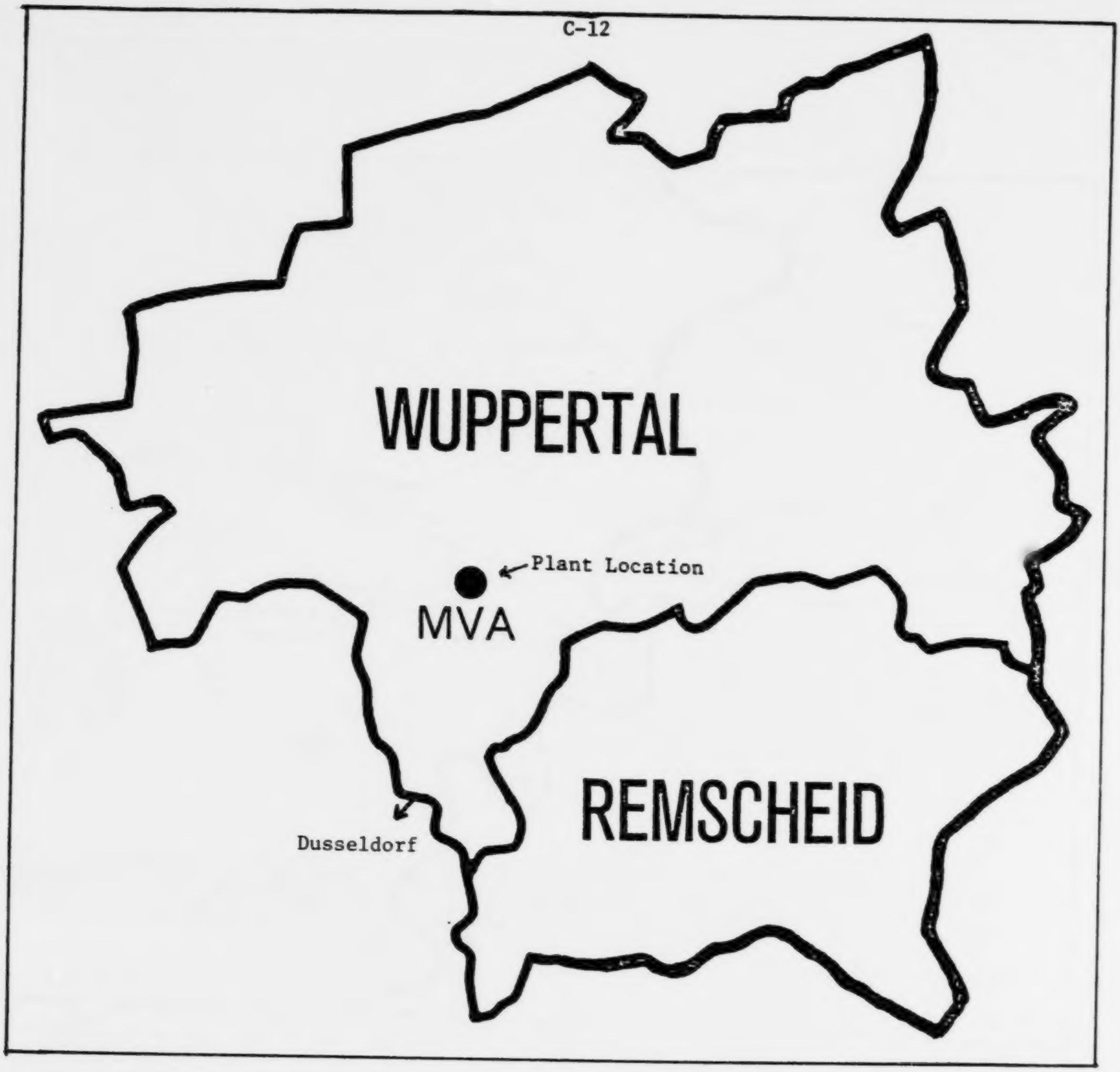
WUPPERTAL
Plant Location
MVA
REMSCHEID
Dusseldorf

FIGURE C-6. REGION SERVED BY WUPPERTAL MVA (MULLVERBRENUNGSANLAGE) [WASTE-BURNING PLANT]
(Courtesy MVA Wuppertal Gmbh)

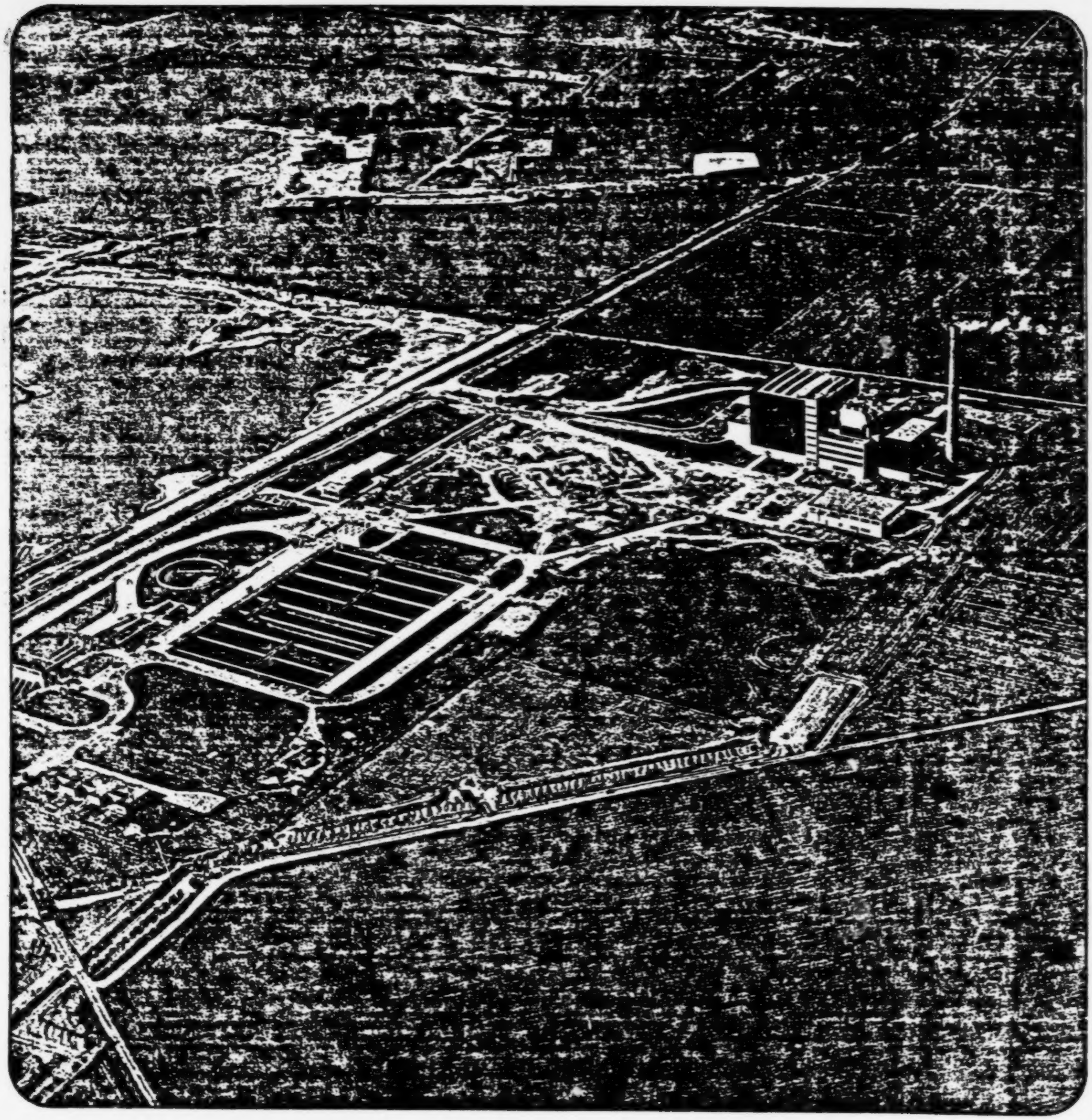

FIGURE C-7. KREFELD WASTE PROCESSING FACILITY; WASTEWATER TREATMENT PLANT ON LEFT, REFUSE-AND SEWAGE-SLUDGE-BURNING PLANT ON RIGHT.

All of the energy available for export from the plant goes to one industry 2.5 km away, in the form of hot water at 130 C (266 F).

An extensive public recreation area and large, attractive shopping center are in operation and undergoing development and expansion in the immediate vicinity of the plant.

Krefeld is an industrial city near the much more intensely industrialized areas of Duesseldorf and Duisburg.

Paris:Issy (France)

The Issy plant is located in the southwest of Paris along the Siene River as can be seen in Figure C-8. The area along the river is flat but sufficiently above the river water level so that no excavation ground water problems were experienced.

Actually the name "Issy-les-Moulineaux" comes from the Paris suburb of that same name. The map also shows the location of the three other major facilities: Ivry, St. Ouen and Romanville. Ivry is similar to Issy. St. Ouen is an older 360,000 tons per year rotary kiln. The Romanville facility is now only a transfer station having ceased burning operations in 1969. Much of the Romanville waste is transferred to Issy at night. There is substantial interaction among all four facilities that are all controlled by one organization.

The greater Paris metropolitan area population is 7,750,000; while that of the City of Paris is 2,790,00. Issy, a suburb, has a population of only 52,000. The remainder of the population is in the 53 other Parisian suburbs.

The employment pattern in government and industry is a diverse and balanced as one would expect of France's capital city and largest city. Heavy industry does not contribute much waste to the Issy plant.

With one exception, the city of Paris has a parallel organizational position with the other 54 suburbs. The plant, therefore, is not run by the cities of Paris or Issy, but by a Federally chartered organization: Electricite' de France. Actually the operations are controlled by EDF's somewhat independent unit: Service du Traitement Industrial des Residus Urbains (TIRU). Much of the information in this report was supplied by the officials in this "Service for the Industrial Treatment of Urban Waste".

The one exception mentioned is that the Department of Seine financed and built the Issy plant. Several years ago, General DeGaullerearranged governmental activities so that the City of Paris continues to own the units but has no operational responsibilities.

Hamburg:Stellinger-Moor (West Germany)

Figure C-9 shows the Stellinger Moor (S-M) plant location in Stellingen, a northwestern suburb of Hamburg. The total metropolitan Hamburg population is 1,800,000. S-M consumes waste from about 500,000 people. Hamburg's population has recently been declining at a rate of 10,000 people per year--as more people move to the suburbs.

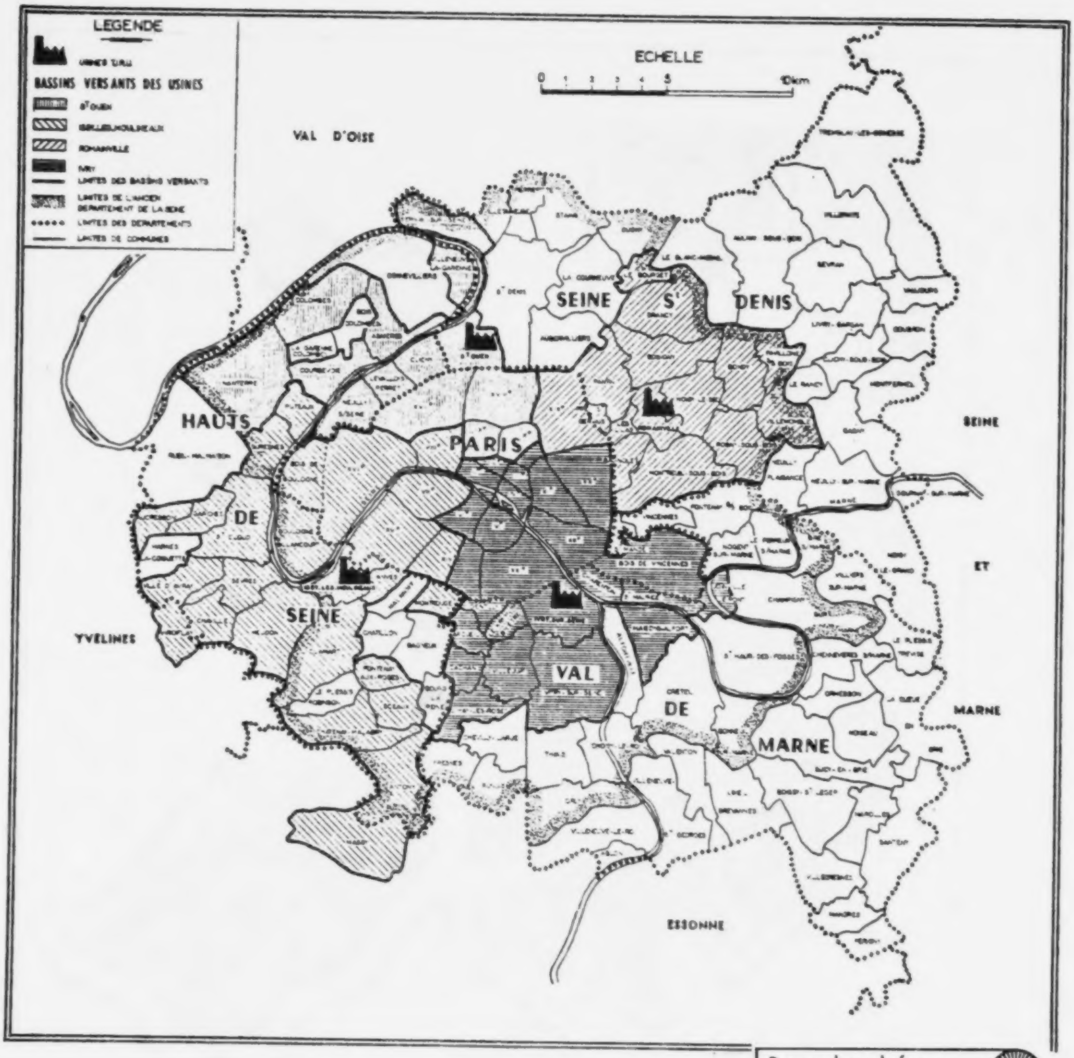
LEGENDE
BASSINS VERSANTS DES USINES
ECHELLE
0 1 2 3 4 5 10km
VAL D'OISE
SEINE
S^T DENIS
HAUTS
DE
SEINE
PARIS
VAL
DE
MARNE
SEINE
ET
MARNE
YVELINES
ESSONNE

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FIGURE C-8. WASTE GENERATION AREA AND TREATMENT PLANTS FOR THE PARIS, FRANCE PLANTS THAT TREAT URBAN WASTE

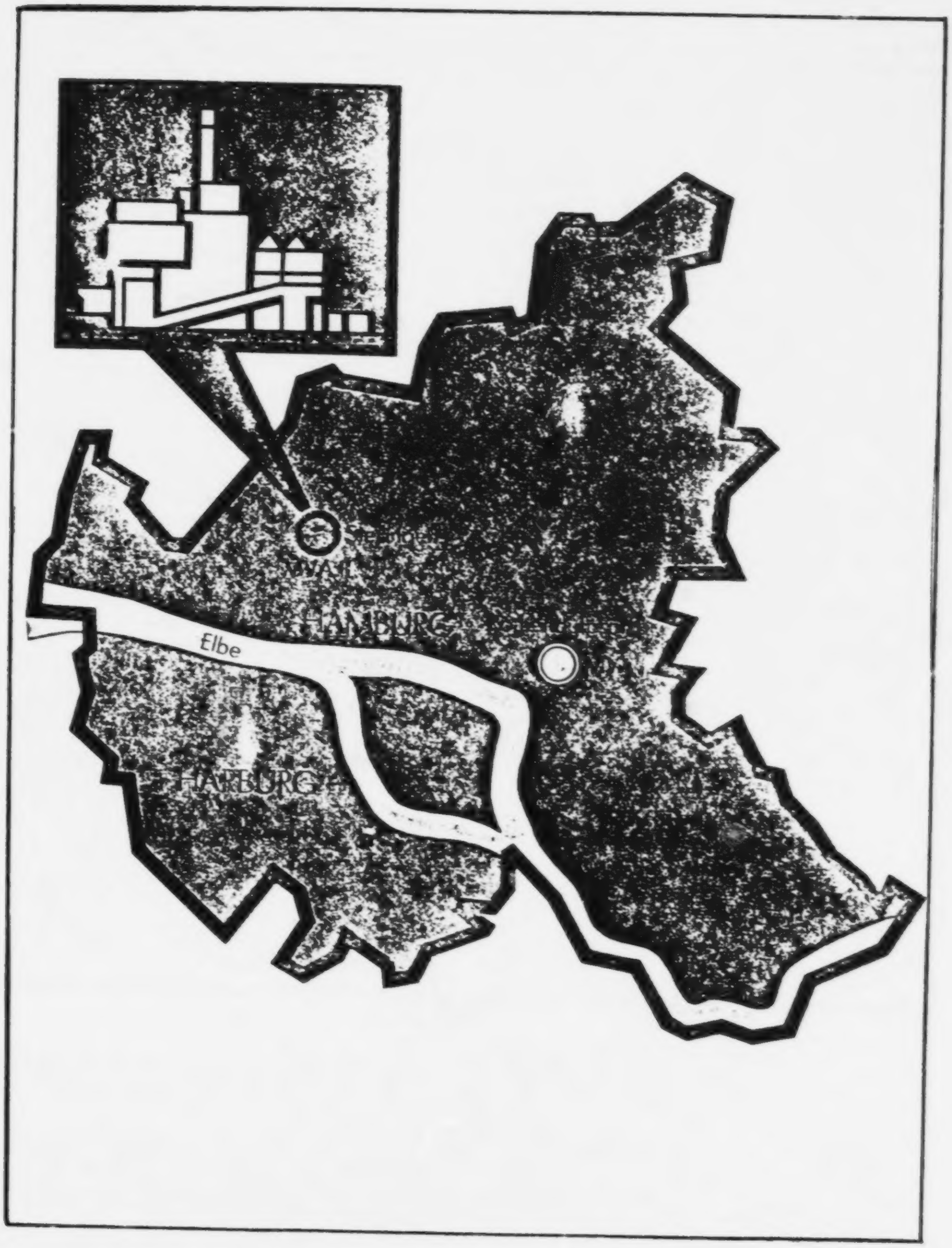

HAMBURG
Elbe
HARBURG

FIGURE C-9. LOCATION OF STELLINGER MOOR PLANT

Being a large industrial city, there are many generators of industrial waste. On two observed occasions, large loads of Agfa film were discharged into the pit. Most of the harbor waste is diverted either to the refuse fired steam generator (RFSG) at Borsigstrasse or landfilled.

The plant itself is located in a sanitary park in an industrial area.

Zurich:Hagenholz (Switzerland)

The Zurich metropolitan area is located in the Northern foot-hills of the Swiss Alps. The land is thus gently rolling except near the suburb of Hagenholz where the terrain is relatively flat.

The City of Zurich has a population of 388,000 people. The Hagenholz plant serves 560,000 people, not only in Zurich but also other neighboring suburbs. The population has recently decreased because Mediterranean workers went home after the "Swiss for the Swiss" referendum. The concurrent world recession has also contributed to a return to family farms and the countryside.

Industry and other employment activities are well diversified. There were no mentionable unique generators of waste that would affect Hagenholz plant operations. Hagenholz is very overloaded. Hence, the city is completely rebuilding the Josefstrasse facility closer to downtown Zurich.

The Hague (The Netherlands)

The Hague is situated on the North Sea on very flat coastal land.

The plant, located in the southwest part of the Hague, is completely surrounded by old residential communities. The plant is adjacent to a large oil-burning municipal power plant and is less than one km (0.6 mi) from the International Peace Palace. Figure C-10 shows the concentrated urban location of the plant.

A population of 550,000 is served: 500,000 of these in The Hague and 50,000 in four small neighboring communities. The population served in 1968 was 450,000 when the plant was built. At present the population of The Hague is not growing, but is decreasing slightly, and the annual tonnage of refuse received has about stabilized around 210,000 tonnes per year (231,000 t/y). The collection area for this plant extends over a radius of about 15 km (9.3 mi) from the plant.

There is no heavy industry. The city is a government center and, because of its location on the sea, is also visited by many tourists during the summer.

Dieppe (and Deauville) (France)

Both Dieppe and Deauville are small resort towns with beaches on the English Channel. They are about 70 miles (110 km) apart. Dieppe, permanent population of 26,000, has been an important industrial port since Roman times because of its excellent harbor, "one of the safest and deepest harbors on the English Channel". It has become an important port, rail, and industrial manufacturing center. Deauville is a very clean seaside resort town on rolling land near Trouville and Le Havre at the mouth of the Seine.

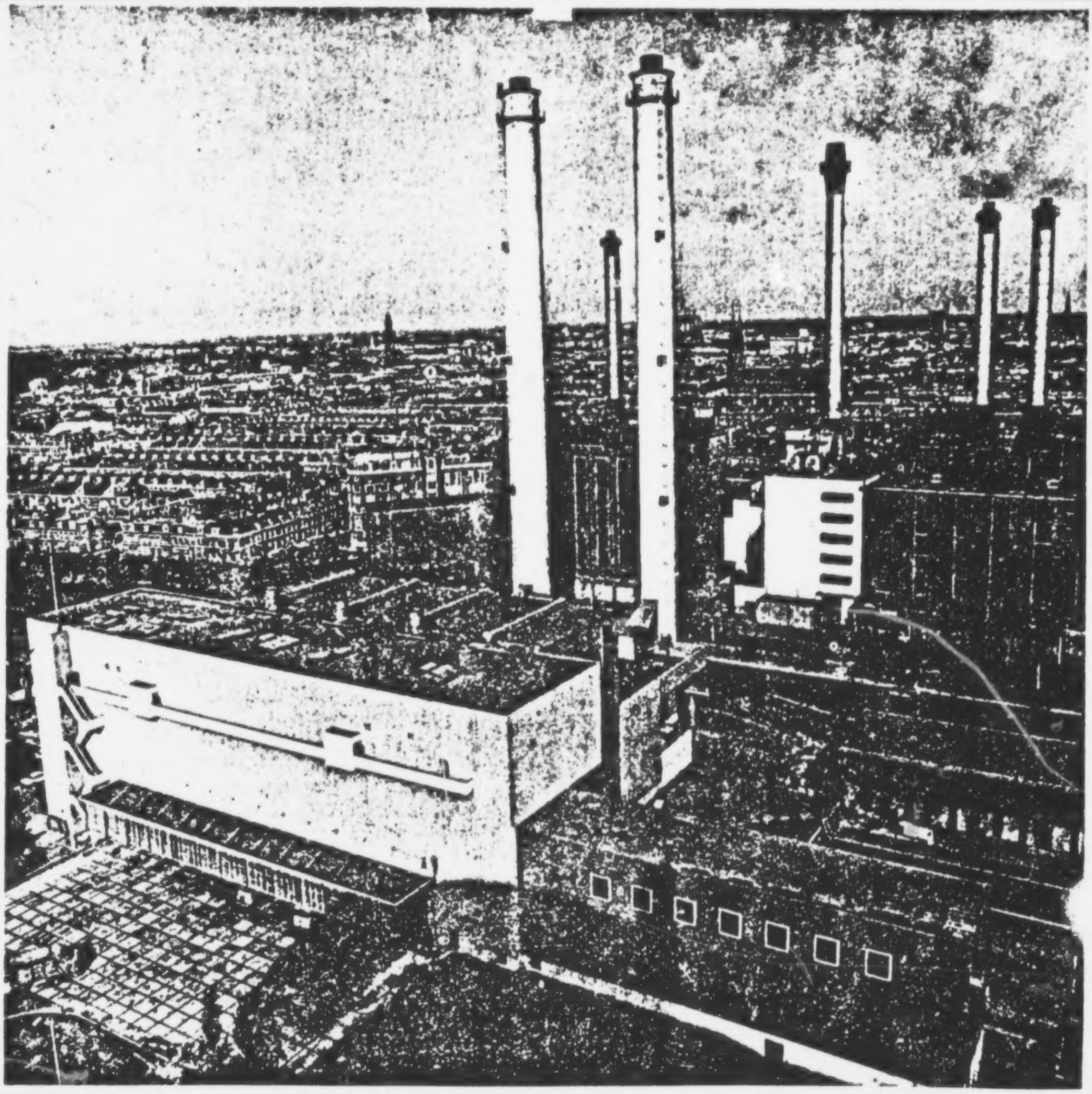


FIGURE C-10. THE HAGUE PLANT SITUATED NEAR THE CENTER OF THE HAGUE. THE FOUR CHIMNEYS IN THE BACKGROUND SERVE THE 200 MW OIL-FIRED MUNICIPAL POWER PLANT (Courtesy GE Vuilverbranding)

It was natural that in order to preserve and enhance the resort feature of their existence, the two towns would be especially interested in handling their wastewater and solid wastes in a clean manner.

Solid waste at the Dieppe plant is received from a 12 km (7 mi) radius area which includes Neuville and five other villages and many industries in very hilly terrain. The total population served is about 48,000. Approximately 10 percent of the refuse received is industrial. Unique waste at the rate of 1.5 tonne/day comes as fiberglass, resin, and paint wastes from the Renault Alpine Sportscar Body Factory. The paint comes in 25 kg (55 lb) plastic bags. Vinyl upholstery scraps did come from a local plant but if too much is charged at once, it melts and clogs the grate. Hence, the amount of this material accepted had to be limited.

Deauville, permanent population of 6,000, is surrounded by adjacent communities with a permanent population of 20,000. However in the summer the wastes from 200,000 vacationers on a typical summer day must be processed. There is no industrial waste in Deauville.

Gothenburg (Sweden) (Also Known As Goteborg)

Gothenburg is a relatively "new" port city founded in 1619 on the hilly southwest coast of Sweden about 120 km (75 mi) across the Kattegat from the northern tip of Denmark. It is the most important industrial center in Sweden.

The Savenas plant is in the suburb of Partille adjacent to a large railway yard between the river Saveon and the main highway to the east called Europaweg 3. Figure C-11 shows the area served which originally included about 36 other towns. Owing to rapid consolidation of communities throughout Sweden, the number of towns now served is nine.

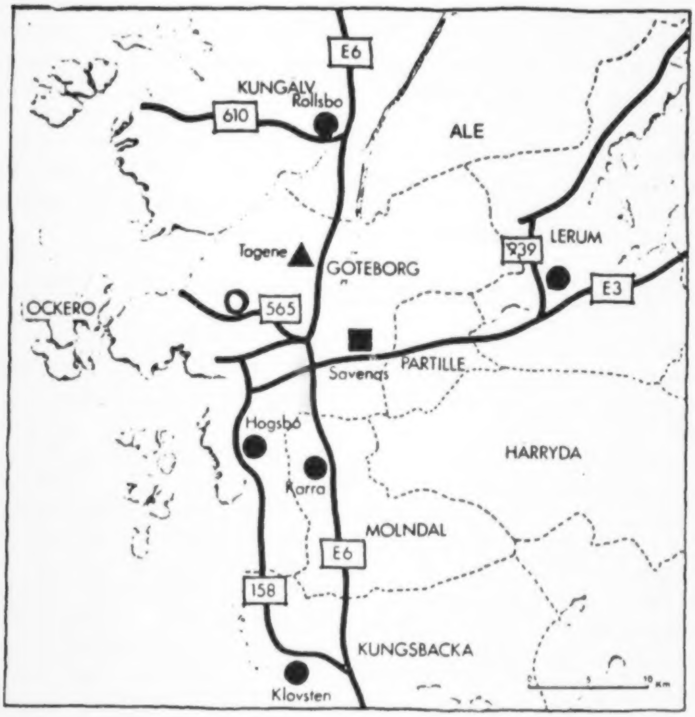
The Gothenburg population is 440,000. The total population served by the Savenas plant is 670,000. About 220,000 tonnes (242,000 tons) of refuse are received annually. Most of the refuse is collected at transfer stations within a radius of about 17 km (10 mi) from the plant.

There are many manufacturing facilities in the area and a considersable fraction of the refuse received is industrial.

Uppsala (Sweden)

The city is over 1,000 years old with a population of about 150,000. It stands 75 km (45 mi) northwest of Stockholm on a plain which is estimated to have been under shallow water as recently as 3,000 to 4,000 years ago as an aftermath of the Ice Age. The community has a long history of being in the forefront of knowledge. The University was 500 years old in 1977. Scheele discovered oxygen and chlorine there about 200 years ago. Linneaus did most of his pioneering botanical research there.

Until 1863, Uppsala was a small town dominated by craft guilds which prevented growth. There was much provety and unemployment. But in 1863, new Swedish laws ended the dominance of the craft guilds and the principal of free trade was established by law. The city then began to grow rapidly. The Uppsala City Council met for the first time in January, 1863. At about the same time, municipal government began for 48 small neighboring communities. The last consolidation was in 1971 when seven rural districts joined. These together now form the municipality of Uppsala.


E6
KUNGALV
Rollsbo
610
ALE
LERUM
939
Tagene
GOTEBORG
E3
OCKERO
565
Savenas
PARTILLE
Hogsbo
HARRYDA
Karra
MOLNDAL
E6
158
KUNGSBACKA
Klovsten
0 5 10 Km

■ Sävenäs incinerator.

▲ New landfill at Tagene.

● Existing transfer stations.
○ Future transfer station
Dist. Sävenäs to Tagene ∿6 mi.

FIGURE C-11. COLLECTION AREA FOR GOTHENBURG WASTE HANDLING SYSTEM. TOTAL AREA SERVED IS ABOUT 1000 km^2 (386 square miles). (Courtesy of GRAAB).

There are 81 councillors, elected every 3 years. Nearly 2,000 citizens are on municipal boards and committees. The city employs 10,000 people. The official city brochure declares: "This story of the development of the city government over the last 100 years is also the story of the rise of democracy in Swedish society and its development into a welfare state".

The service sector dominates Uppsala's industry and comprises 67 percent of the total employment. The largest industry, Volvo-Bagslogsverken, produces auto parts and outboard motors. Fortia-Pharmacia has 1,250 employees and sends blood plasma substitutes worldwide. One quarter of the industrial employment is in workshop industries, in graphics, food processing, wood, and cement products. Much active research is evolving new products.

Horsens (Denmark)

Horsens "town of horse power" is an industrial and seaport city of 54,000 population located at the head of the Horsens fjord on the island of Jutland. In 1970, its population was about 38,000, but as part of the consolidation of communities throughout Denmark, Horsens was at that time combined with five other communities.

Figure C-12 is a map of the expanded Horsens community, which has a land area of about 200 km^2 (38.6 mi^2). To provide more fuel for its refuse-to-energy plant, Horsens is seeking agreements with surrounding communities. One town, Gedved, population 10,000 located 10 km (6 mi) northof Horsens, has arranged to send all of its refuse to Horsens. On the map in Figure C-12 Gedved is near the top center.

The countryside is fairly hilly with many small towns closely spaced and connected by many roads. A north-south expressway, E3, passes through the western part of the city. Two of the neighboring towns use hearth-type incinerators, but in 1980, the law requires that these be shut down.

Figure C-13 is an aerial view of the Horsens plant and, at the top, the new wastewater treatment plant. About one fourth of the weight of solid waste received at the plant is industrial waste. There are three plastics plants in town which produce waste of high heat value. Also, there are electronics plants and a telephone factory.

There are 15 communities around Horsens which comprise a region or "small state" called an AMT (similar to a city-county government). The trend of Danish communities to combine to form "AMT" regions is an old one which has been found good for making road decisions, regional planning, conducting refuse management studies, environmental review, and for exercising sanction power, which is the authority to stop practices that harm the environment. An AMT council is elected every 4 years. The plans for the Horsens refuse plant were approved by the AMT council.

Copenhagen:Amager (Denmark)

Figure C-14 is a map of the Copenhagen:Amager's waste collection service area. Copenhagen itself is located on the east coast of Denmark, not far from Sweden.

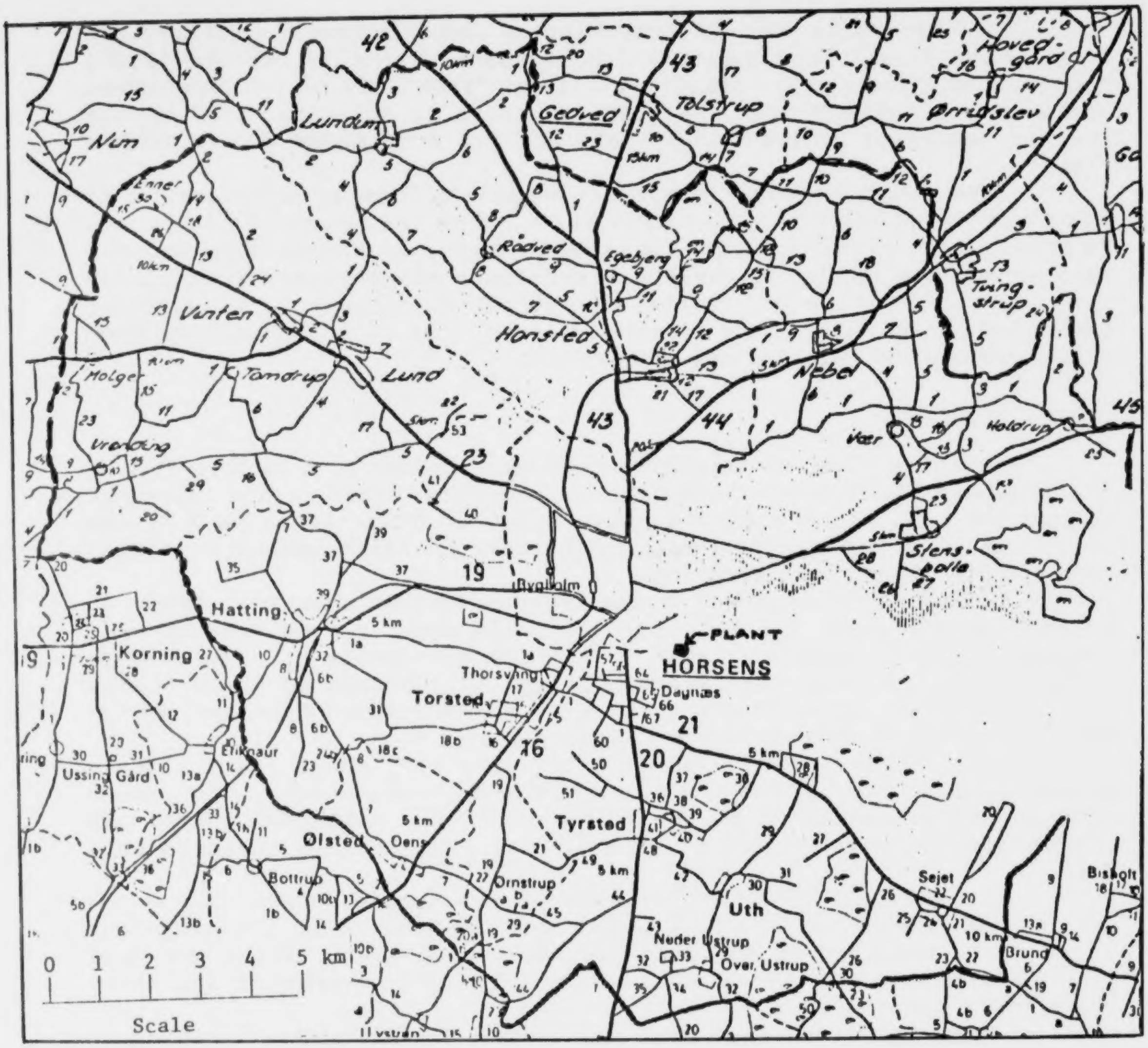

Num
Lundum
Gedved
Tolstrup
Hoved-gård
Ørridslev
Vinten
Rådved
Egebjerg
Tvingstrup
Hansted
Lund
Tamdrup
Nebel
Holdrup
Vær
Stensballe
Hatting
Korning
Bygholm
PLANT
HORSENS
Thorsvang
Torsted
Dagnæs
Ussing Gård
Elkjær
Tyrsted
Ølsted
Bottrup
Ørnstrup
Uth
Nedre Ustrup
Over Ustrup
Sejet
Bisholt
Brund
42
43
44
45
23
19
16
20
21
5 km
10 km
0
1
2
3
4
5
km
Scale

FIGURE C-12. MAP OF AREA SERVED BY HORSENS REFUSE PLANT. THE COMBINED HORSENS COMMUNITY SERVED IS ENCLOSED IN THE HEAVY BROKEN LINE.

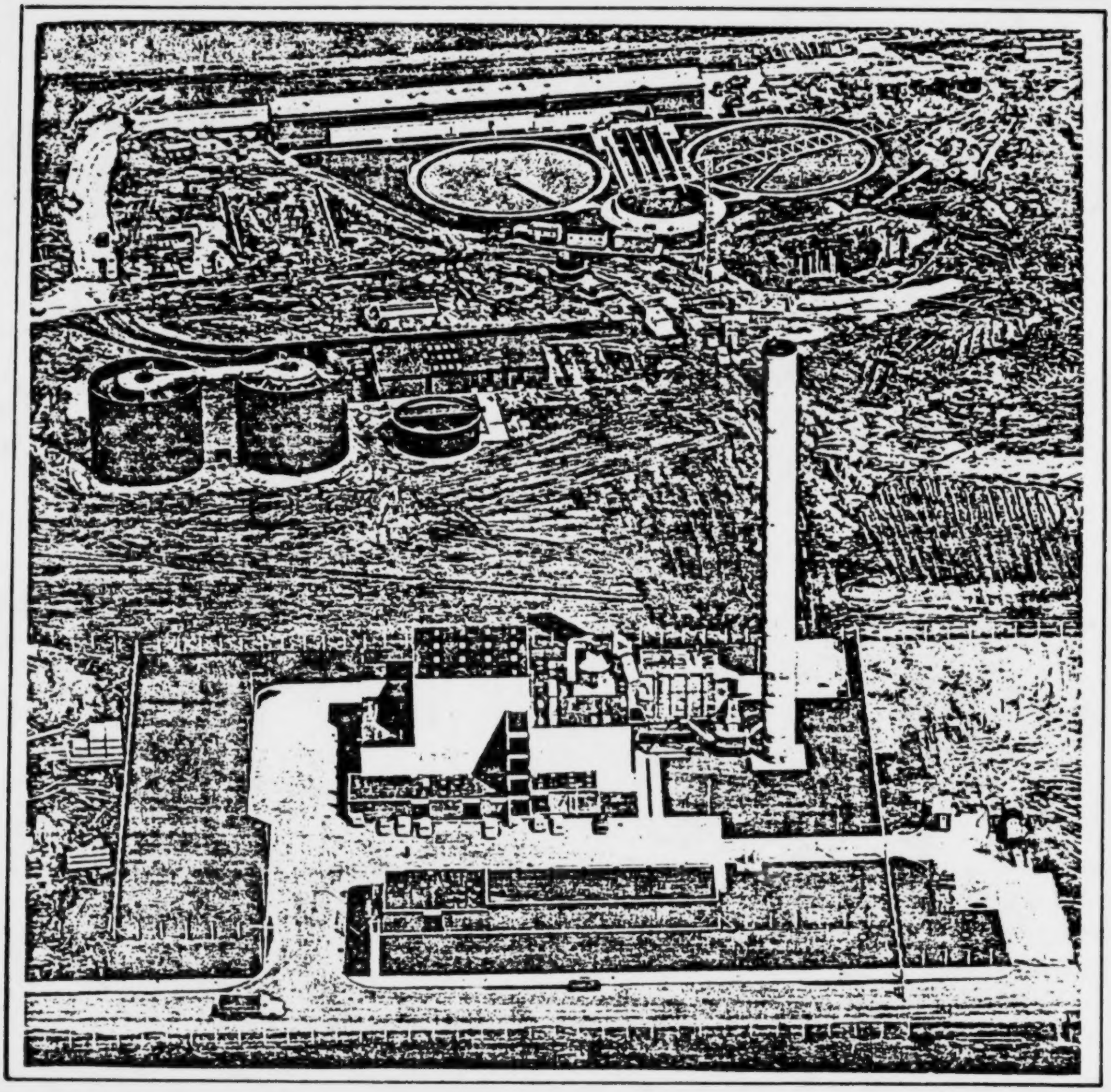


FIGURE C-13. AERIAL VIEW OF HORSENS REFUSE-BURNING, SLUDGE-DRYING AND DISTRICT-HEATING PLANT. AT TOP IS THE NEW SEWAGE TREATMENT PLANT. AT FAR LOWER RIGHT IS A COLLECTION STATION FOR HAZARDOUS LIQUID WASTE WHICH IS SENT TO THE NATIONAL HAZARDOUS WASTE CENTER AT NYBORG (COURTESY OF BRUUN AND SORENSEN)

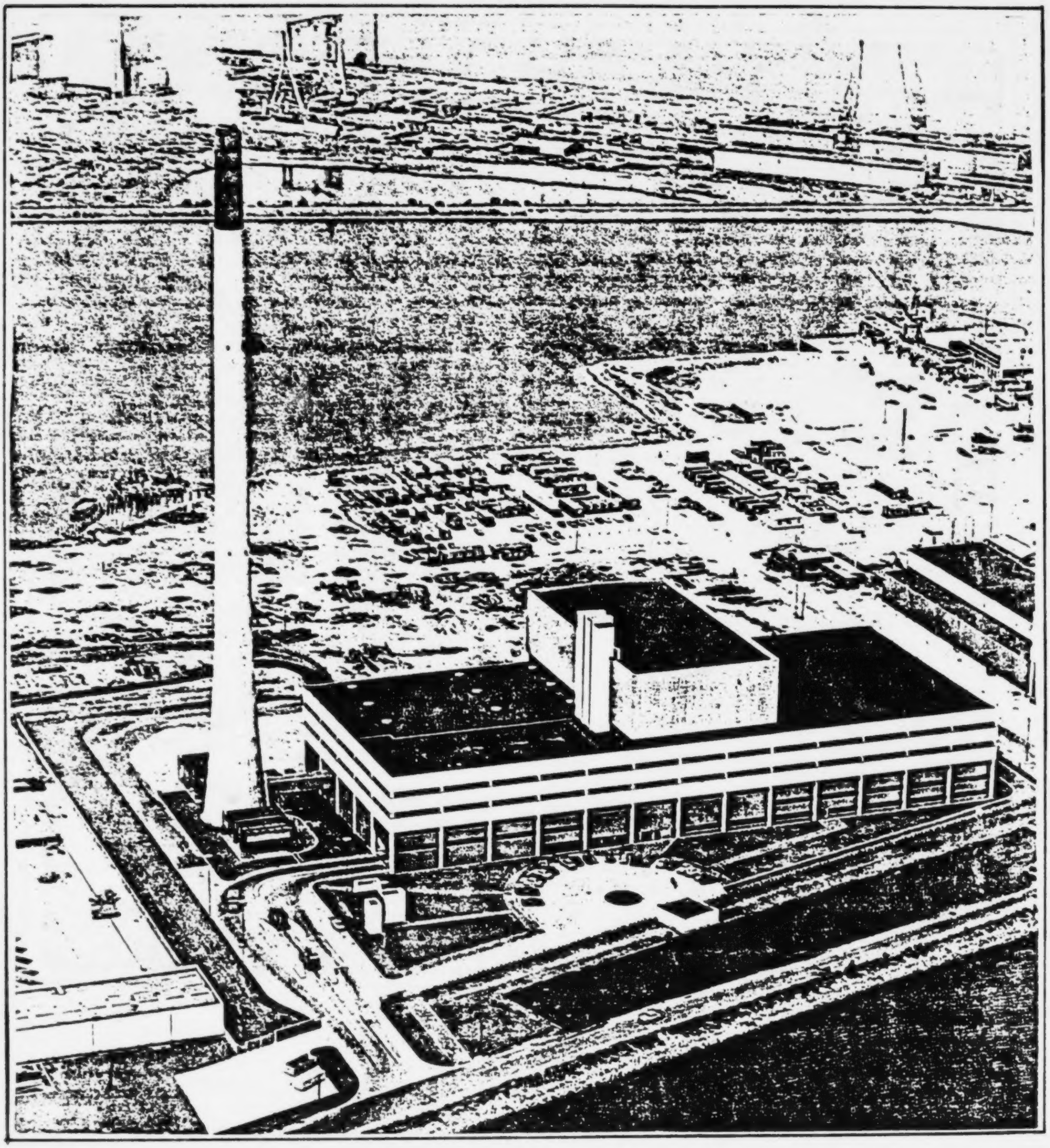


FIGURE C-14. COPENHAGEN:AMAGER PLANT LOCATED ON CANAL

The Amager refuse-fired steam generator is shown at the north end of Amager Island southeast of downtown Copenhagen.

The terrain is rather flat, which is typical of eastern Denmark. The Amager plant (see Figure C-15) is located right on the canal separating Amager Island from the main Danish island to Amager's north. Amager Island was originally unimproved swamp land that has been "poldered" with pilings, dykes and debris fill over many centruies. Being at sea level did interfer with construction in two ways. First, numerous pilings had to be sunk. Secondly, the refuse bunker pit had to be shallow and encased in special water protective coatings.

The population in the city of Copenhagen proper has fallen from 550,000, 10 years ago, to 430,000 presently. Reasons are typical of those in many large cities. Basically young families are moving to the suburbs leaving the city for students, government workers, retired people, and those wishing a short commute to work. The Amager plant serves about 620,000 people in central, east, and southern Copenhagen and those residents of the Amager Island.

Copenhagen:West (Denmark)

Figure C-16 is a larger map of the Copenhagen metropolitan area.

The West (Vest) refuse fired steam generator (Vestforbranding) is shown along with its twin unit on the Amager Island just southeast of downtown Copenhagen.

The plant is surrounded by open space. Adjoining this land are summer garden plots and light industry. There are no particular geographical features that impacted plant construction. The primary site location consideration was to be at the intersection of two main highways as shown in Figure C-17.

The West plant serves about 620,000 people in western Copenhagen and eleven of its western and northern suburbs.

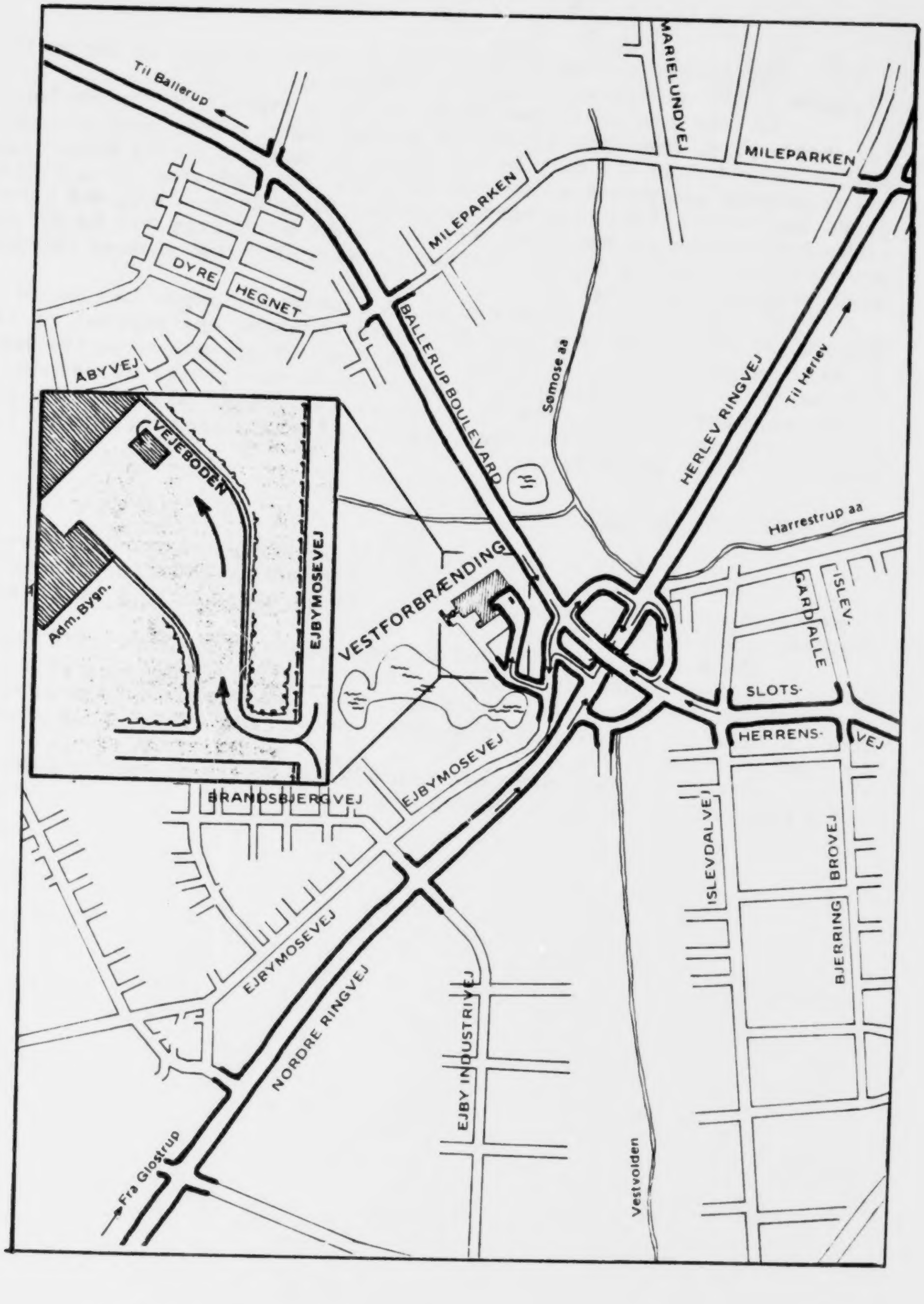

Til Ballerup
MARIELUNDVEJ
MILEPARKEN
MILEPARKEN
DYRE
HEGNET
ABYVEJ
BALLERUP BOULEVARD
Somose aa
HERLEV RINGVEJ
Til Herlev
Harrestrup aa
VEJEBODEN
Adm. Bygn.
EJBYMOSEVEJ
VESTFORBRÆNDING
ISLEV.
GARDALLE
SLOTS-
HERRENS-
VEJ
BRANDSBJERGVEJ
EJBYMOSEVEJ
ISLEVDALVEJ
BROVEJ
BJERRING
EJBYMOSEVEJ
NORDRE RINGVEJ
EJBY INDUSTRIVEJ
Fra Glostrup
Vestvolden

FIGURE C-15. DETAILED MAP SHOWING LOCATION OF WEST PLANT AT THE INTERSECTION OF TWO MAJOR HIGHWAYS

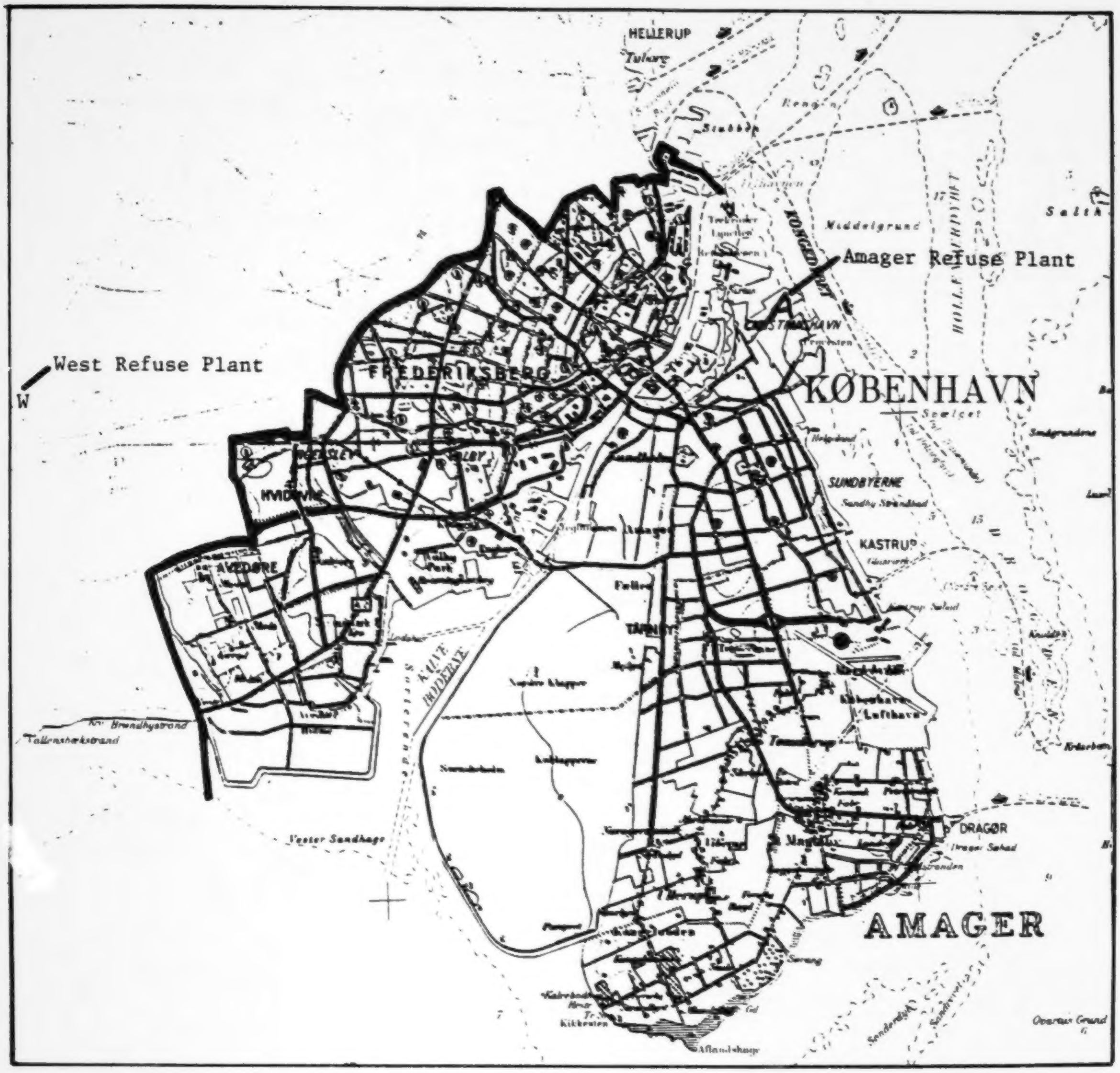

HELLERUP
Amager Refuse Plant
West Refuse Plant
W
FREDERIKSBERG
KØBENHAVN
CHRISTIANSHAVN
Middelgrund
HVIDOVRE
AVEDØRE
SUNDBYERNE
KASTRUP
TÅRNBY
DRAGØR
AMAGER
KONGEDYBET
HOLLÆNDERDYBET
Vester Sandhage
Kalvebod

FIGURE C-16. MAP OF COPENHAGEN, SOUTH AND EAST METROPOLITAN AREA SERVED BY THE AMAGER PLANT

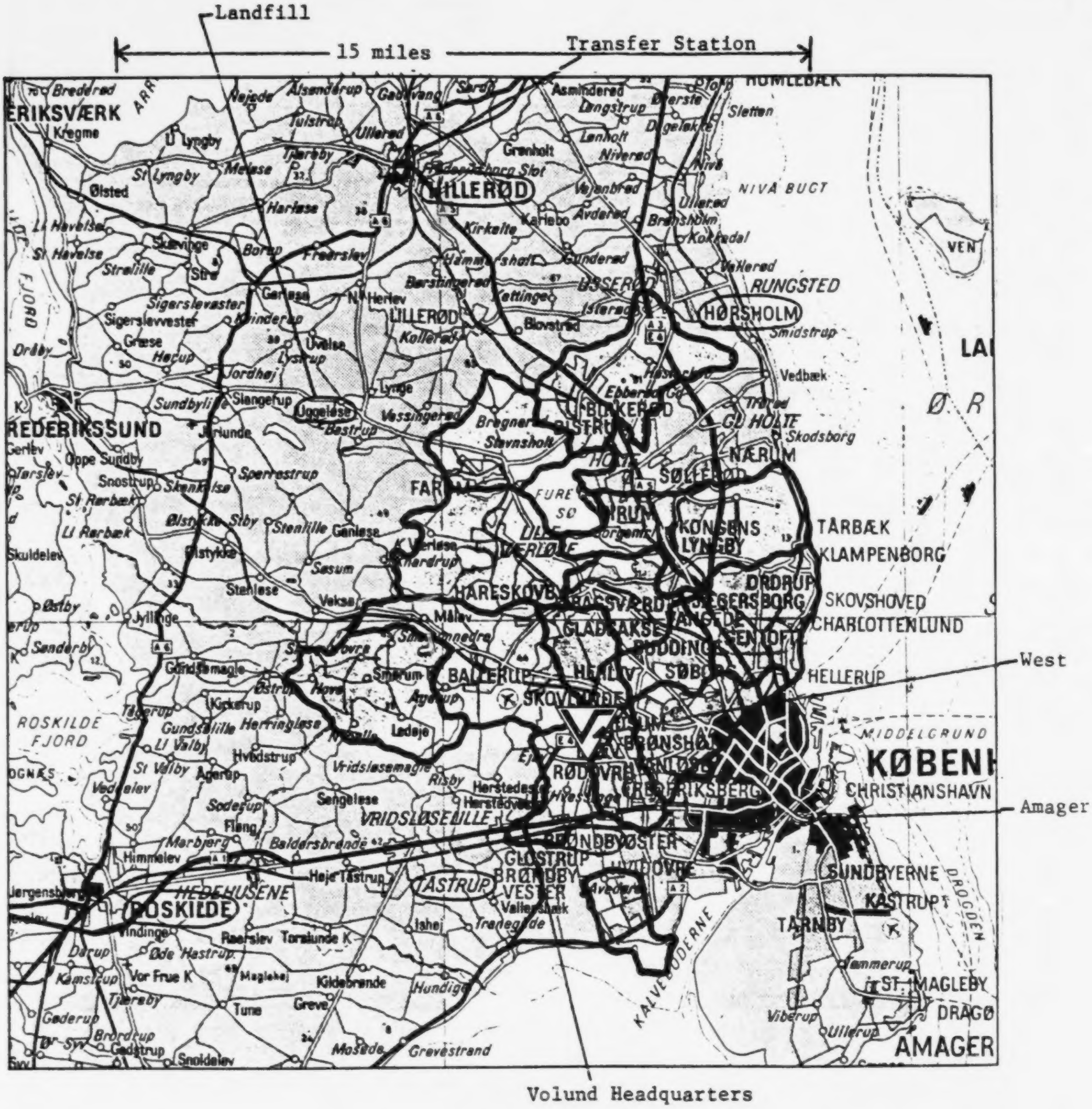

Landfill
15 miles
Transfer Station
West
Amager
Volund Headquarters
HUMLEBÆK
HILLERØD
LILLERØD
HØRSHOLM
RUNGSTED
NIVÅ BUGT
VEN
FREDERIKSSUND
FARUM
KONGENS LYNGBY
NÆRUM
TÅRBÆK
KLAMPENBORG
SKOVSHOVED
CHARLOTTENLUND
HELLERUP
HARESKOVBY
BALLERUP
SKOVLUNDE
GLADSAXE
BRØNSHØJ
RØDOVRE
FREDERIKSBERG
KØBENH
CHRISTIANSHAVN
MIDDELGRUND
GLOSTRUP
BRØNDBY VESTER
HVIDOVRE
TÅSTRUP
ROSKILDE
ROSKILDE FJORD
HEDEHUSENE
VRIDSLØSELILLE
SUNDBYERNE
KASTRUP
TÅRNBY
DROGDEN
ST. MAGLEBY
DRAGØ
AMAGER
KALVEBODERNE

FIGURE C-17. MAP OF GREATER COPENHAGEN AREA SHOWING THE LOCATION OF THE WEST (VEST) REFUSE FIRED STEAM GENERATOR, THE HILLERØD TRANSFER STATION, VOLUND HEADQUARTERS, ETC.

SEPARABLE WASTE STREAMS

General Comments

As mentioned in the introduction, this report is concerned not only with the burning of refuse, but also with the handling of all waste materials within the same facility. Many of the observed facilities include three or more separate waste-stream systems. Table D-1 summarizes waste streams associated with each facility that are treated independently from the main refuse burning waste stream.

One of the unexpected observations to report regarding visits to the 30 refuse burning facilities is that there are usually multiple and separate waste streams flowing into the same property. Perhaps due to socialism or age of the community, there is a greater sense of environmental planning and physical integration among system modules. There are many examples of synergistic benefits experienced by combining not only environmental modules (refuse burning, waste-water treatment, animal rendering, etc.) but also the energy modules (district heating, electricity generation, etc.) within the same facility. This theme is expanded in a previous chapter, "Environmental and Energy Parks". Each waste stream category is summarized below.

Household, Commercial and Light Industrial Refuse (i.e. the Main Waste Stream)

The focus of the project is to examine in detail the treatment of the household, commercial, and light industrial waste stream. All 15 facilities process this waste stream. Later sections will discuss in detail refuse collection, transfer stations, and physical and chemical composition.

Bulky and Large Industrial Wastes

Eight of the 15 facilities have shears to size bulky and large industrial waste to 1 meter (3 feet) or less. Treatment of these bulky wastes is described in a later section, "Size Reduction of Bulky Refuse". Only Duesseldorf has a shredder; it is seldon used.

The large Martin hoppers and furnaces will accept bulky waste of reasonable size. None of the Martin plants visited had shears. However, at each plant, there was encouragement for acceptance of only household, commercial, and light industrial waste. The few large pieces are broken by a falling grab bucket.

At Copenhagen: Amager the bulky waste is taken to the crusher transfer station adjoining the refuse-burning plant (see Figure D-1). Reasonably sized construction debris and other noncombustible material is packed directly into transfer trailers. These noncombustible loads are then taken to a landfill. However, bulky combustible materials first pass through a shredder before being compacted into a trailer. The combustible loads are then taken a short distance to the refuse-burning plant.

TABLE D-1. WASTE STREAMS TREATED INDEPENDENTLY FROM THE MAIN REFUSE BURNING WASTE STREAM

	TOTAL	Werdenberg-Liechtenstein	Baden-Brugg	Duesseldorf	Wuppertal	Krefeld	Paris:Issy	Hamburg:Stellinger-Moor	Zurich:Hagenholz	The Hague	Dieppe (and Deauville)	Goteborg	Uppsala	Horsens	Copenhagen:Amager	Copenhagen:West
Household, Commercial & Light Industrial	15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bulky & Large Industrial	8	X	X	X	X	X				X		X			X	
Waste Water	5	X	X			X					X			X		
Sewage Sludge	6	X	X			X					X			X		X
Source and Front-End Separation																
Paper & Cardboard	1															X
Iron, Steel, & White Goods	3					X				X						X
Bottles	2									X						X
Copper in Motors	1									X						
Tires	1									X						
Used Crank Case Oil	3		X						X					X		
Waste Oil Emulsions	3		X						X					X		
Oil Sludges	2								X					X		
Waste Solvents	2								X					X		
Industrial Chemicals	3								X					X	X	
Hazardous Wastes	4		X						X					X	X	
Dextrose Sludge	1												X			
Animal Waste	4	X							X			X	X			
Street Sweepings	1									X						
Construction Debris	3									X				X	X	
Demolition Debris	2									X				X		
Ash	1													X		
Junk Cars	1													X		

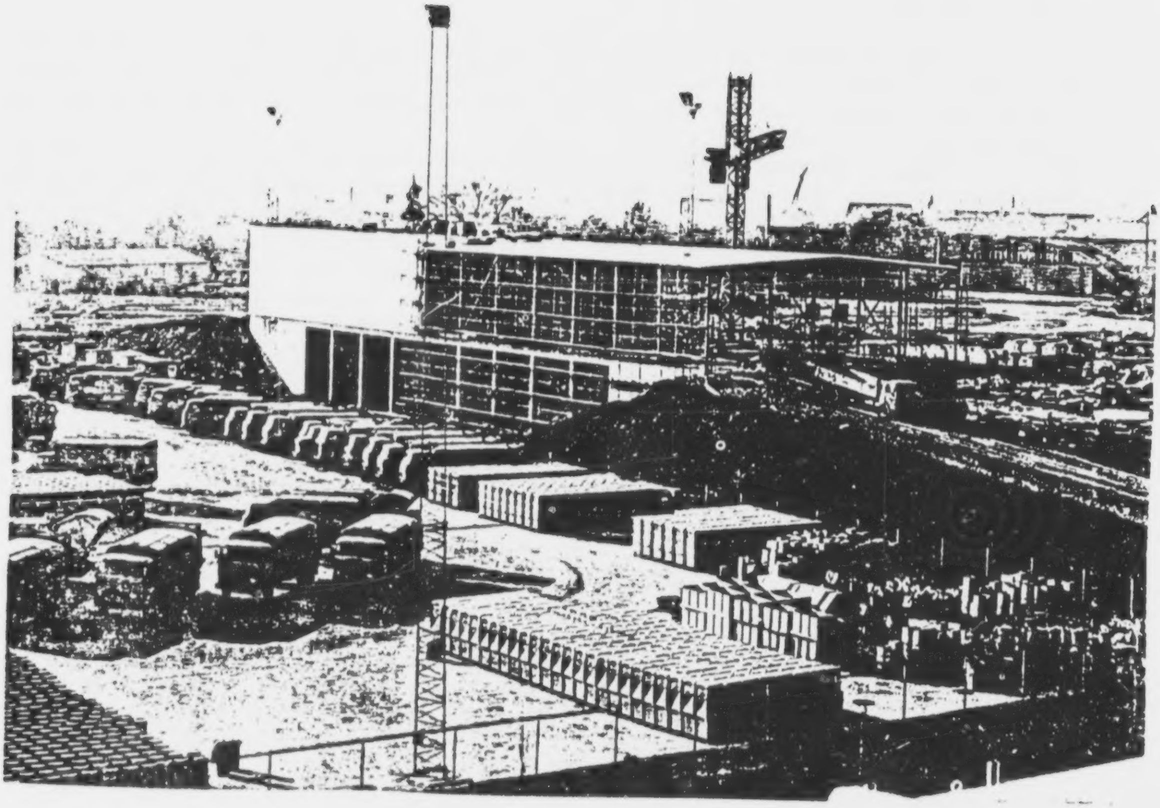


FIGURE D-1. TRANSFER STATION UNDER CONSTRUCTION AT AMAGER. PHOTO TAKEN FROM WINDOW AT THE AMAGER REFUSE BURNING PLANT. THE STORAGE YARD OF THE RENHOLDNINGS SELSKABET COLLECTION ORGANIZATION IS SHOWN IN BETWEEN.

Wastewater and Sewage Sludge

Five of the facilities have wastewater treatment plants coterminous with the refuse burning plant. Sanitary services in Europe are often centralized and well coordinated, In four of the plants, the energy value in refuse is utilized to drive off moisture in the sludge. Three of these plants then burn the dried sludge. Much more information is contained in a later section on "Co-disposal of Refuse and Sewage Sludge".

Source Separation

Source separation is practiced spotily in Europe as it is in the U.S. Its success varies depending on markets, transportation distance, price, and conservation attitudes. The two source separation programs observed were in Denmark.

Near Copenhagen:West, several recycling centers are located at shopping centers. In addition, one of the recycling centers is located at the entrance to the West plant (see Figure D-2). The picture shows a source separation truck discharging sorted items into several of the recycling bins placed near, but before the scale house. Homeowners and businessmen who appreciate the need for recycling can drive their own vehicles to the refuse urning plant and can then place their discarded items into any of these several containers.

We were told that these and other source separation programs detract no more than 10 to 15 percent of the potential heat value from the waste-to-energy system.

Zurich has just started three voluntary recycling centers for glass, cans, and waste paper. The city has had seven centers for collection of used crankcase oil. Garages and private individuals bring their waste oil to the centers. However, no money changes hands.

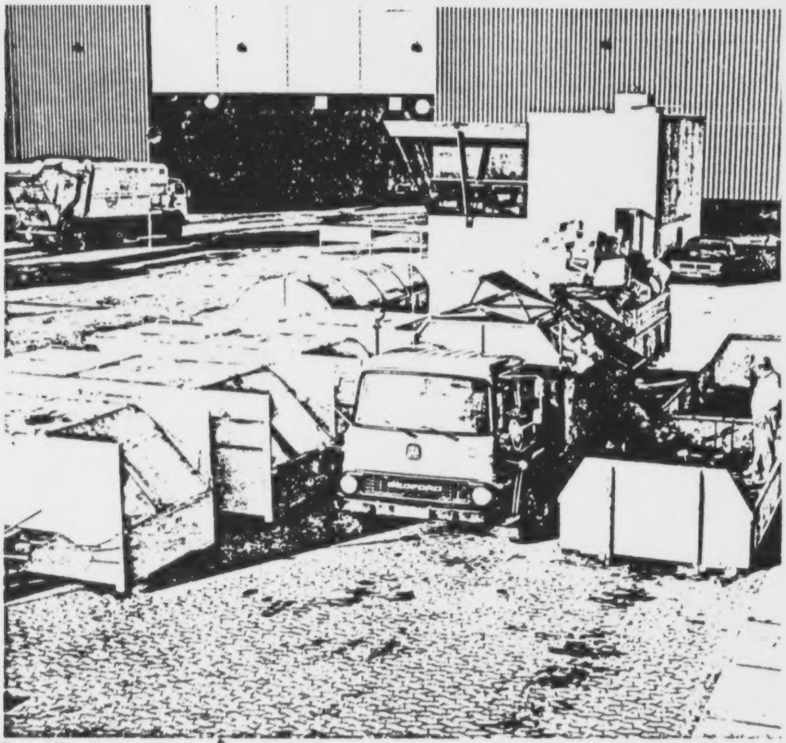
At Baden-Brugg, about 35 percent of the waste glass generated is recycled through a residential pickup system using special containers.

Around Werdenberg-Liechtenstein, there are some shopping center-type recycling centers where people can bring newspapers, bottles, and cans. Color-sorted glass can be sold for 60 S.Fr per tonne ($26.40 per ton) while noncolor sorted glass can be sold at 40 S.Fr. per tonne ($17.60 per ton).

Front-End Separation

The most elaborate front-end separation system observed during the 30 visits was at The Hague (See Figures D-3, D-4 and D-5). Private haulers often bring a combination load in on flat bed or dump trucks. The white goods are off-loaded and then the other bulky combustibles are put into the private haulers pit. A workman then attempts to remove the copper-rich motor. Rubber tires are stacked. Then the shovel loader crumples and smashes the stove or refrigerator for better storage and handling.

The only shredder observed among all of the 30 plants was at Duesseldorf. The Hazemag shredder was down on both of Battelle's visits in 1976 and 1977. However, because ferrous metal is not separated, this can not really be classified as a front-end separation system.



Recycling Station

↑

Paving Cinder Blocks Made From Recovered Ash

FIGURE D-2. SOURCE SEPARATION RECYCLING STATION AT COPENHAGEN: WEST

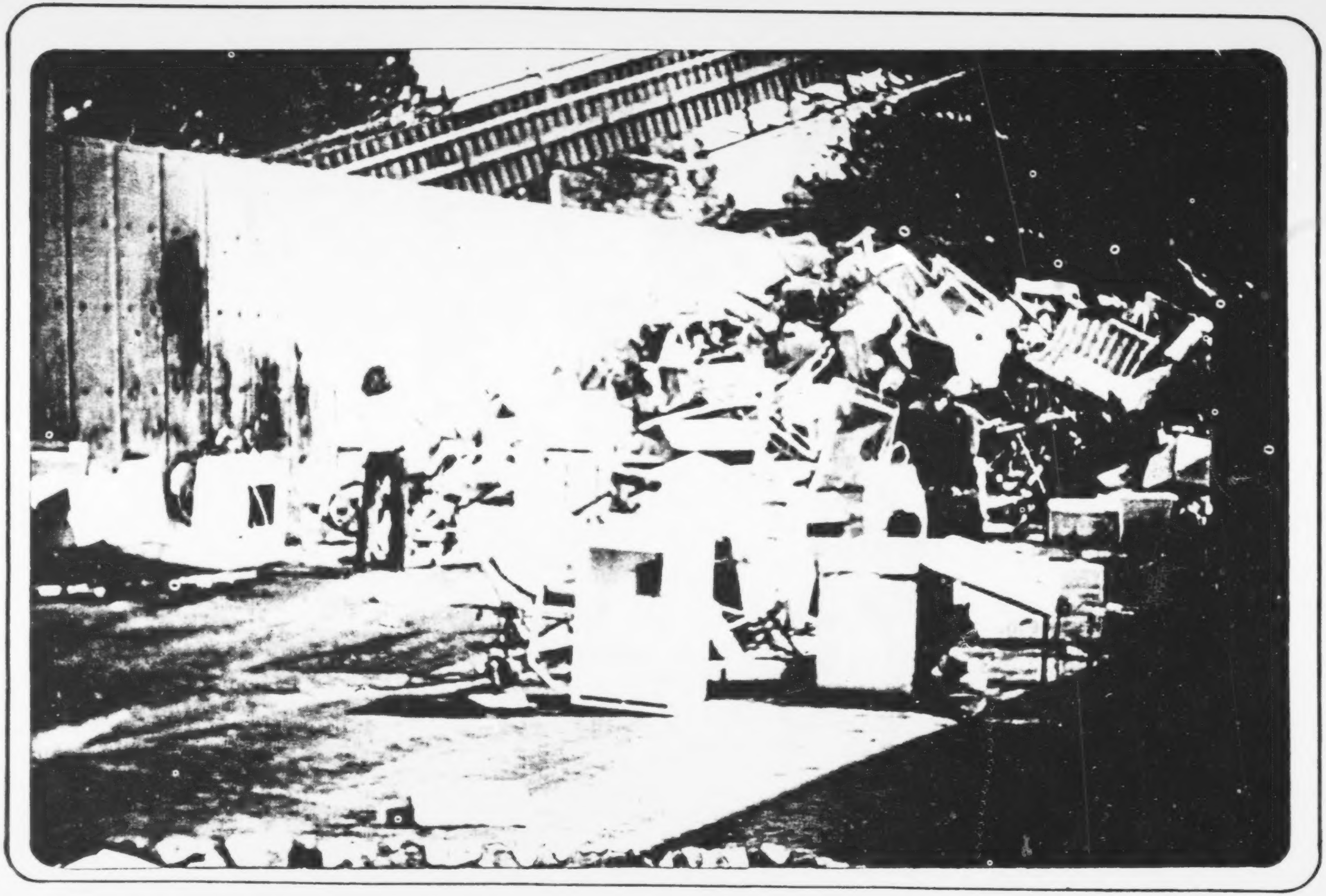


FIGURE D-3. WHITE GOODS, BICYCLES, ETC., RECLAMATION AT THE HAGUE (Battelle photo)

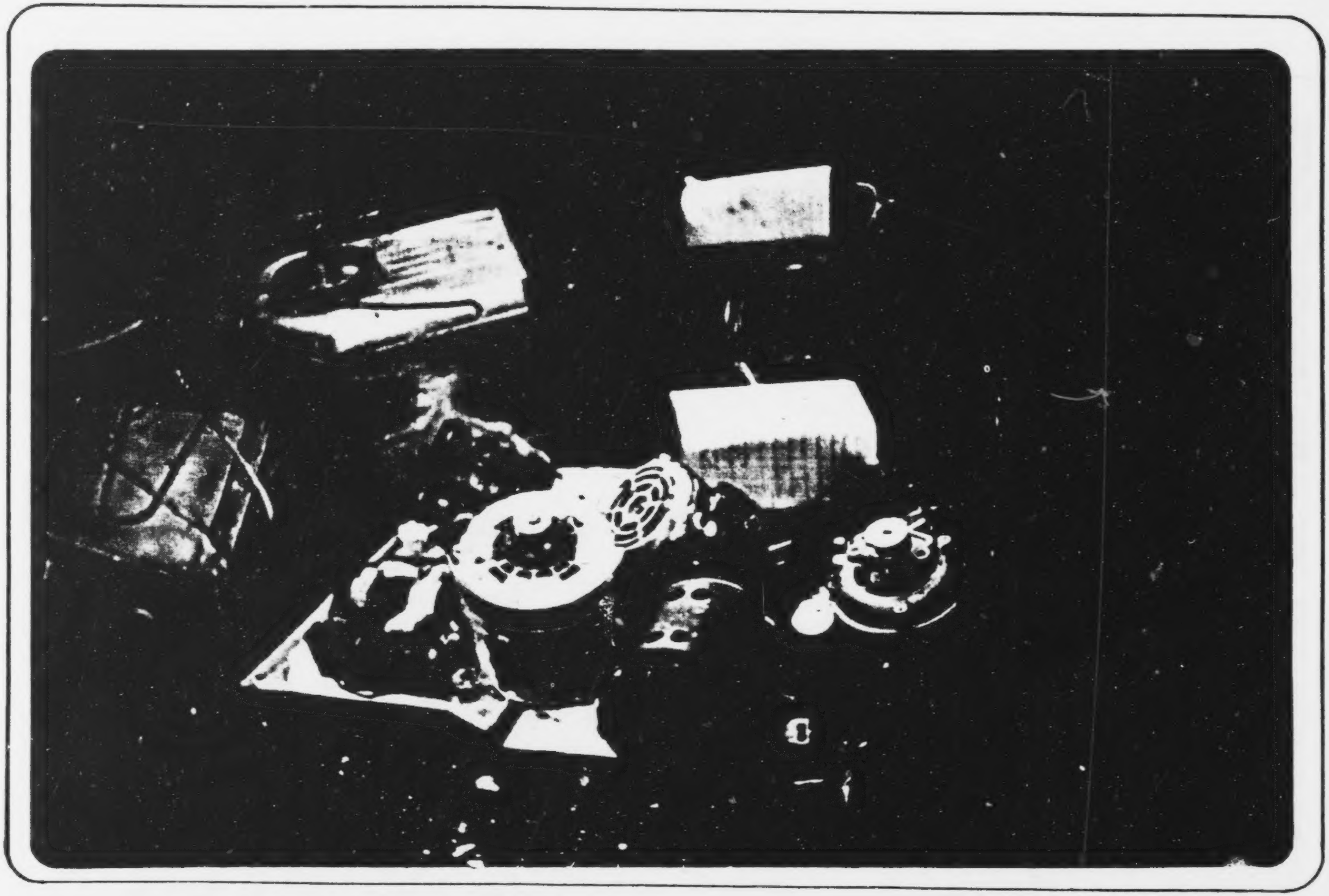


FIGURE D-4. FRONT END SEPARATION OF COPPER-RICH MOTORS AND TIRES IN SCRAP DEALER'S AREA AT THE HAGUE (Battelle photo).

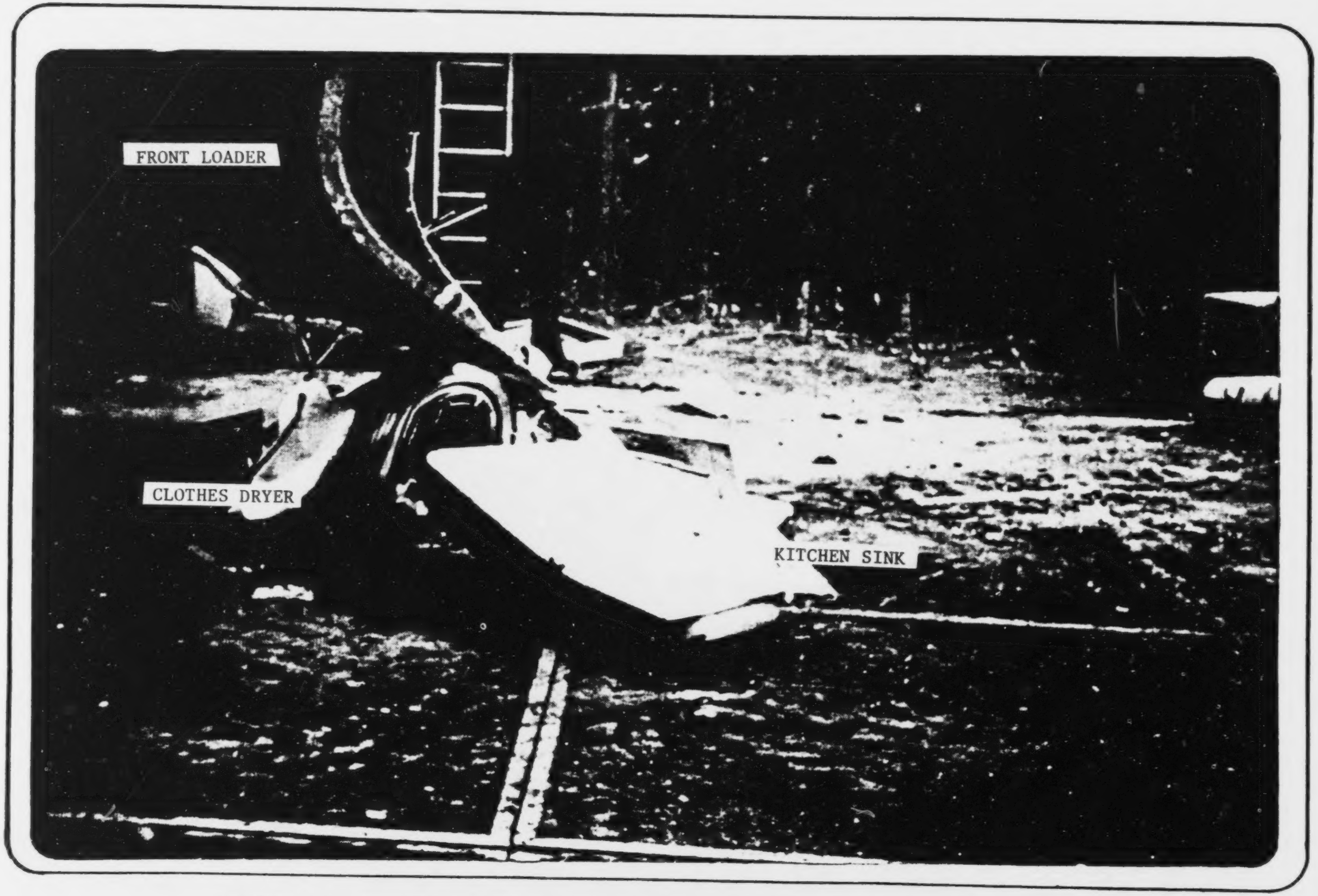

FRONT LOADER
CLOTHES DRYER
KITCHEN SINK

FIGURE D-5. CRUSHING WHITE GOODS AFTER MOTOR REMOVAL
IN SCRAP DEALER'S AREA AT THE HAGUE (Battelle photo).

At Uppsala, (See Figure D-6) there is a single bin for ferrous materials in a corner of the tipping floor. The only real "American type front-end system" operating daily on a full scale is at Birmingham, England. It was inspired by U.S. EPA's demonstration project in St. Louis, Missouri. Because Battelle staff did not visit this Imperial Metal Industries (IMT) facility and because of its relevance to U.S. cofiring development, a summary by IMI's John Marshall is included in the appendix.

Waste Oils and Solvents

Waste crankcase oil, oil emulsions, oil sludges, and solvents are processed at two of the facilities. At Baden-Brugg, the oils are carefully processed in a decanting facility. Nearby at Zurich:Hagenholz, waste oils are decanted and then mixed with more volatile solvents. Details of decanting, mixing and burning are presented later in the Cofiring Section.

Industrial Chemicals and Hazardous Wastes

There is a distinct attitude difference in Europe compared to the U.S. with regard to the public sector's responsibility in handling hazardous waste. One-third of the 15 facilities have on the same or neighboring properties a capability to handle industrial chemical or hazardous wastes. At Baden-Brugg, the neighboring old compost plant has been purchased by a private company (Daester-Fairtec A.G.) and has been converted into an inorganic heavy metals hazardous waste processing center. This plant has several independent processing lines using ion exchange, evaporation, activated carbon, filtering, decontamination, and neutralization

The Zurich:Hagenholz plant receives hazardous wastes from local industry and transfers it to the appropriate hazardous waste treatment centers. Some goes to Braden-Brugg and some will go to the elaborate Swiss government facility being built at Geneva.

In Uppsala, Sweden, the local pharmaceutical company produces a dextrose sludge. This material is fed to a special hazardous waste incinerator adjoining the refuse-burning plant. Off-gases are sent to the hot-air-mixing chamber just after the refuse burner for hydrocarbon destruction.

Denmark, in an exceptionally fine piece of Federal legislation, now carefully controls all hazardous wastes. All industrial generators are required to take their waste to an approved hazardous waste receiving station. When enough waste has been collected, it is transported, usually by rail to Nyborg, Denmark for ultimate processing. Observed collection centers are at Horsens and Copenhagen:Amager (See Figure D-7). A description of this Von Roll designed and constructed Nyborg plant is included in the appendix.

Animal Waste

Animal waste enters the gates of four facilities. A trip highlight was to see the new rendering plant at Zurich:Hagenholz. Animal carcasses, butcher shop trimmings, etc. are rendered into flesh meal, animal feed, and soap. This new plant was purposely located next to the refuse burning

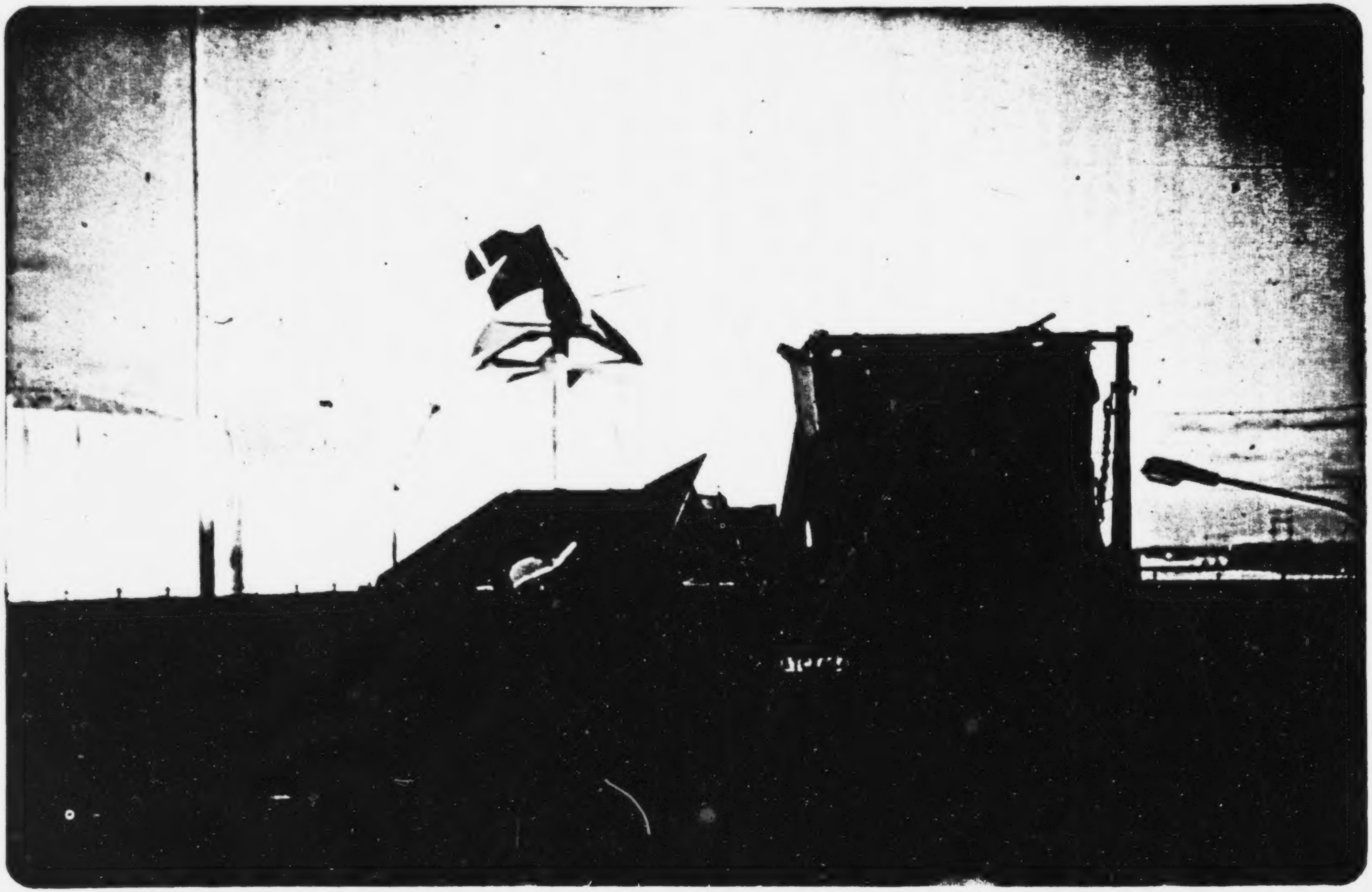


FIGURE D-6. FERROUS MATERIAL BIN IN CORNER OF TIPPING FLOOR AT UPPSALA (Battelle photo).

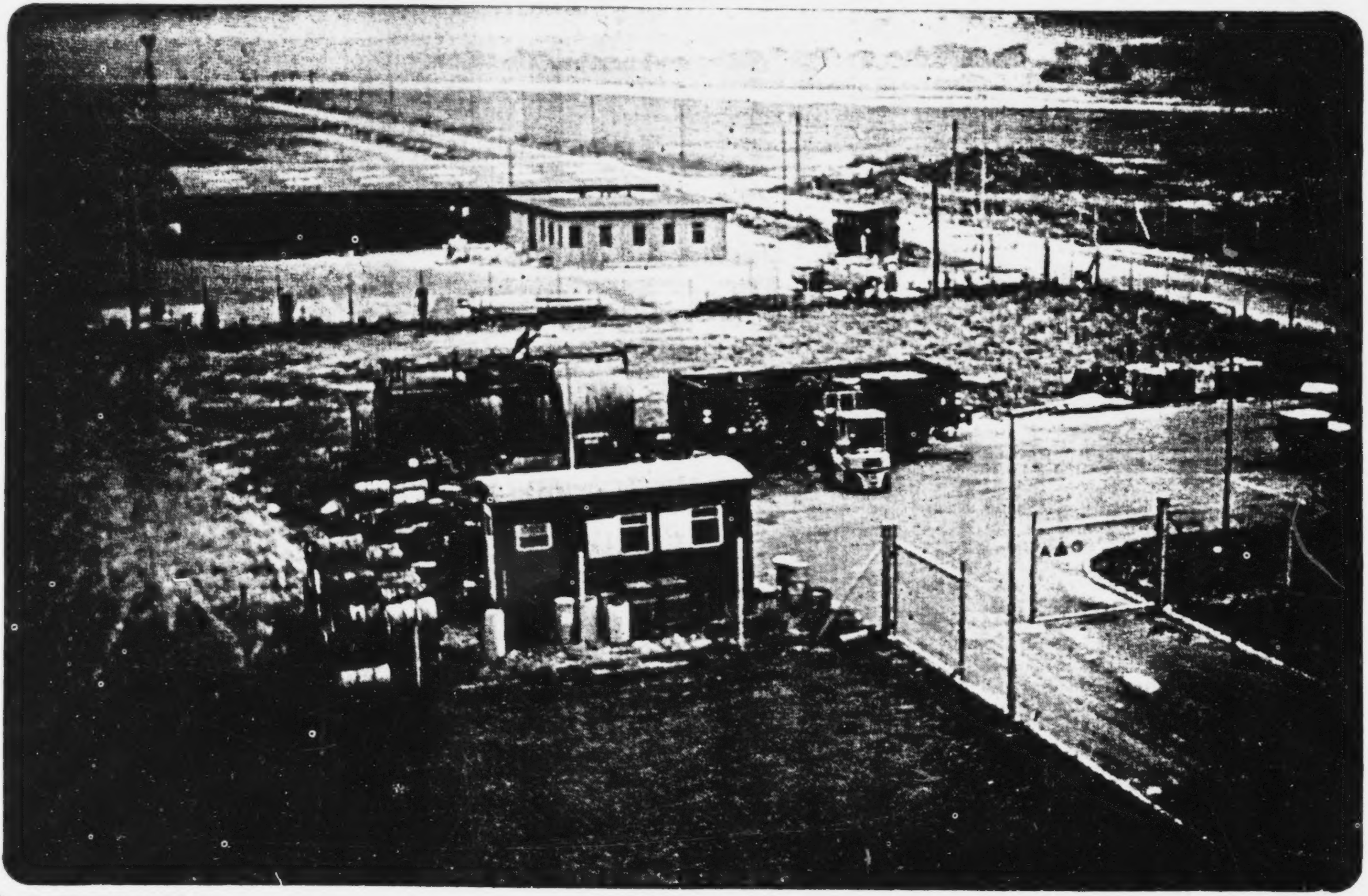


FIGURE D-7. INDUSTRIAL CHEMICAL AND HAZARDOUS WASTE COLLECTION CENTER AT HORSENS (Battelle photo).

plant. The rendering plant's ventilation system was carefully designed to collect odoriferous ambient temperature room air. The air is sent from the rendering plant to the refuse burning plant in the pipe shown in Figure D-8. The contaminated air is injected directly into the refuse furnace as high pressure secondary air.

Comment: There are many synergistic benefits from connecting these two environmental modules next to each other are:

(1) A rendering plant can be designed for maximum ventilation to improve the interval workplace atmosphere.

(2) Noxious and offensive rendering odors outside the plant can be eliminated.

(3) The rendering plant would neither have to use large quantities of expensive natural gas in a fume incinerator or have to use expensive ozone (O_3) in an air bleacher.

(4) A constant ambient temperature (60 to 80 F) source of air for the refuse furnace is assured regardless of outside weather conditions, i.e. an air preheater is not necessary.

(5) Odoriferous gases such as ammonia, mercaptas, hydrogen sulfide, hydrocarbons, and other reduced gases can be converted to H_2O, CO_2, and SO_2.

(6) While not proven, there is speculation that use of rendering gases at Zurich may have assisted in minimizing corrosion to 0.1 to 0.3 mm of metal wastage on superheater tubes after 30,000 hours, i.e., sulfur causes harmless sulfate deposits on the tubes while chlorine is chemically eliminated as a deposit element. The chlorine remains in the HCL gaseous form and exits from the chimmey.

Street Sweepings

The only facility observed to handle street sweepings as a separately controlled waste is at The Hague. Street-sweeping vehicles use the scale before dumping their load off a ramp (See Figure D-9) and into a detachable container. The load is taken to a landfill. Actually the only connection with the refuse burning activity is the common scale and common management.

Construction, Demolition Debris, and Ash

Construction debris is also brought to The Hague and placed in detachable containers for eventual placement in a landfill (See Figure D-10).

The Horsens plant is located on top of the old landfill and adjoining the still active landfill jutting out into the sea. Thus, the total facility consumes locally generated construction and demolition debris and ash.

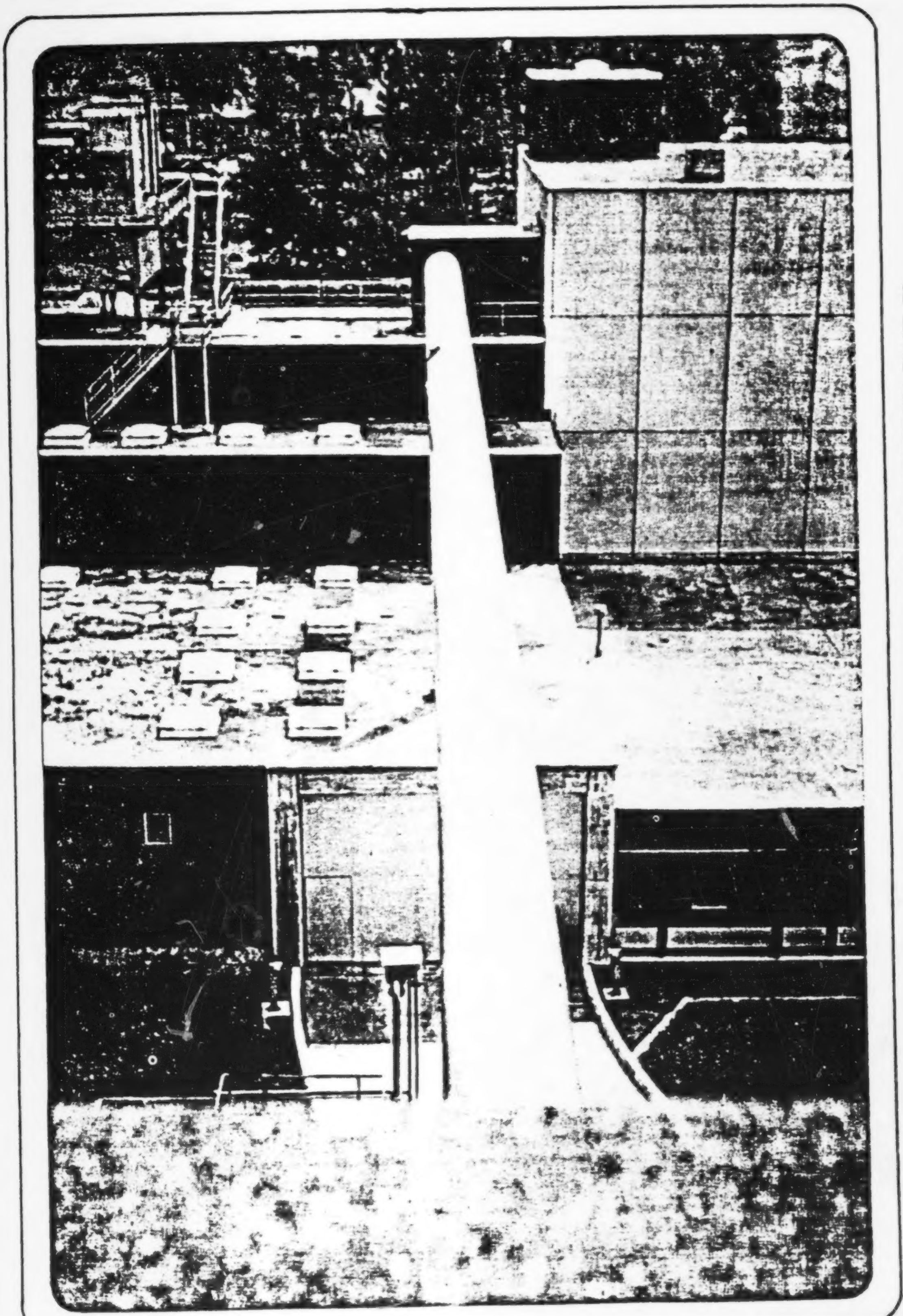


FIGURE D-8. HORIZONTAL VENTIALATION AIR PIPE FROM RENDERING PLANT TO ZURICH: HAGENHOLZ PLANT (Battelle Photograph)

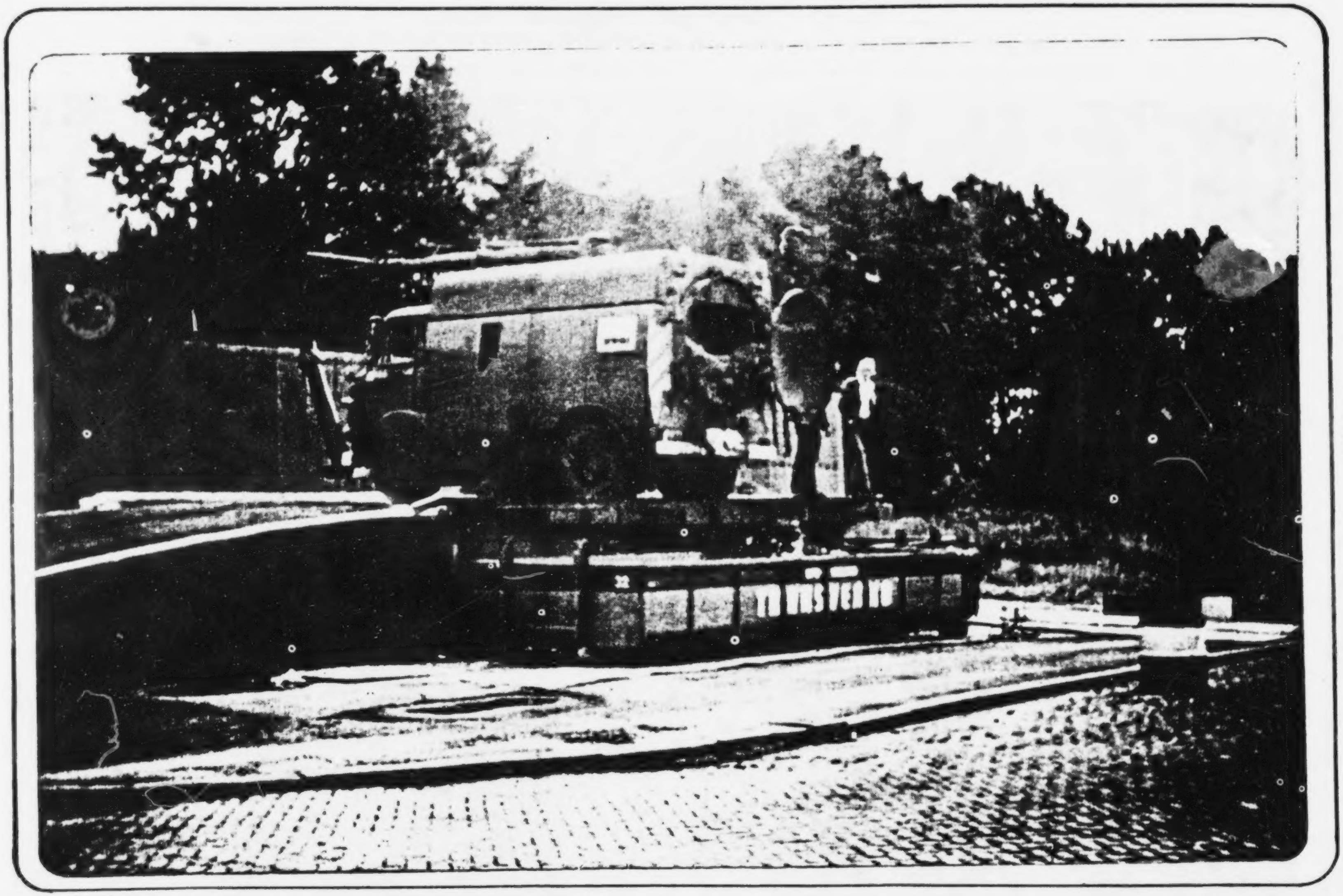


FIGURE D-9. STREET SWEEPING TRUCK OFF-LOADING AT THE HAGUE (Battelle photo).

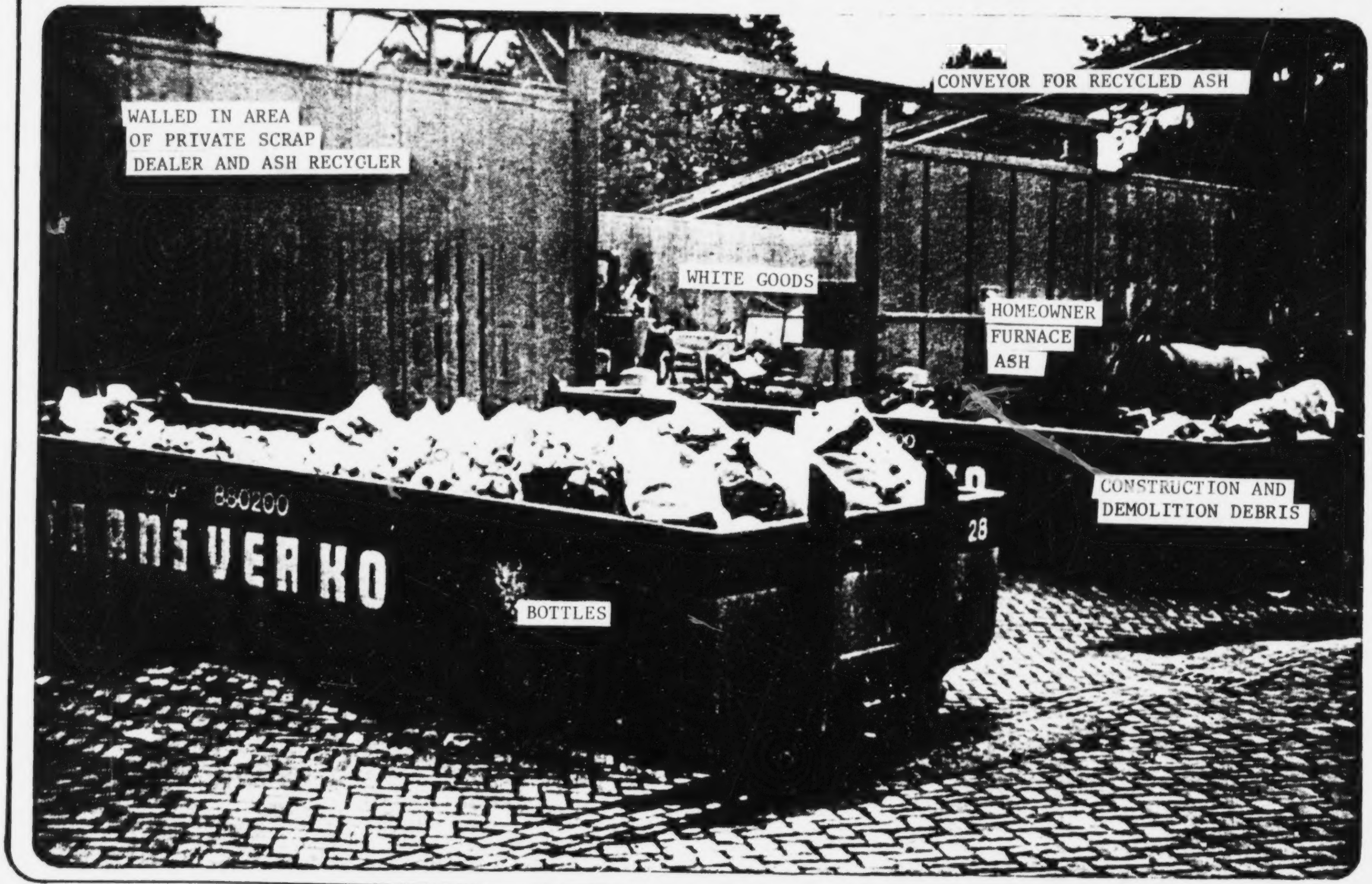

WALLED IN AREA
OF PRIVATE SCRAP
DEALER AND ASH RECYCLER
CONVEYOR FOR RECYCLED ASH
WHITE GOODS
HOMEOWNER
FURNACE
ASH
CONSTRUCTION AND
DEMOLITION DEBRIS
BOTTLES
880200
ANSVERKO
28

FIGURE D-10. FRONT AND BACK END MATERIALS SEPARATION AT THE HAGUE (Battelle photo).

Junk Automobiles

Some of the same Horsens community owned land has been leased to a car and truck junk dealer which is located adjoning the refuse burning plant (See Figure D-11).

Interrelation of Waste Streams

Figure D-12 appears in the April 1976 issue of The Volund. Incinerator Group (VIG) News. It presents the community's waste streams and treatment alternatives: many of which have been implemented.

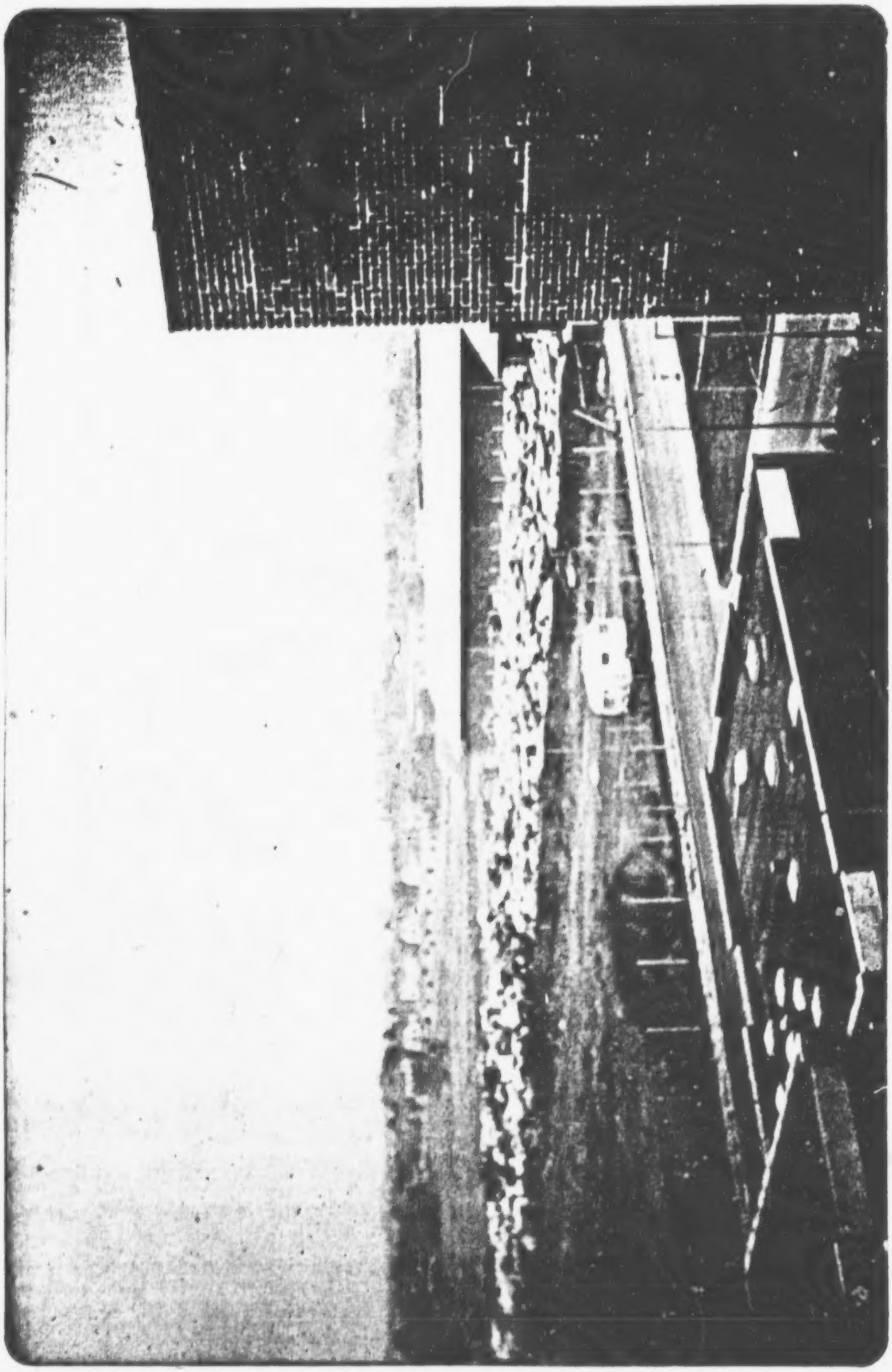


FIGURE D-11. AUTOMOBILE JUNK YARD NEXT TO REFUSE BURNING PLANT AT HORSENS (Battelle photo).

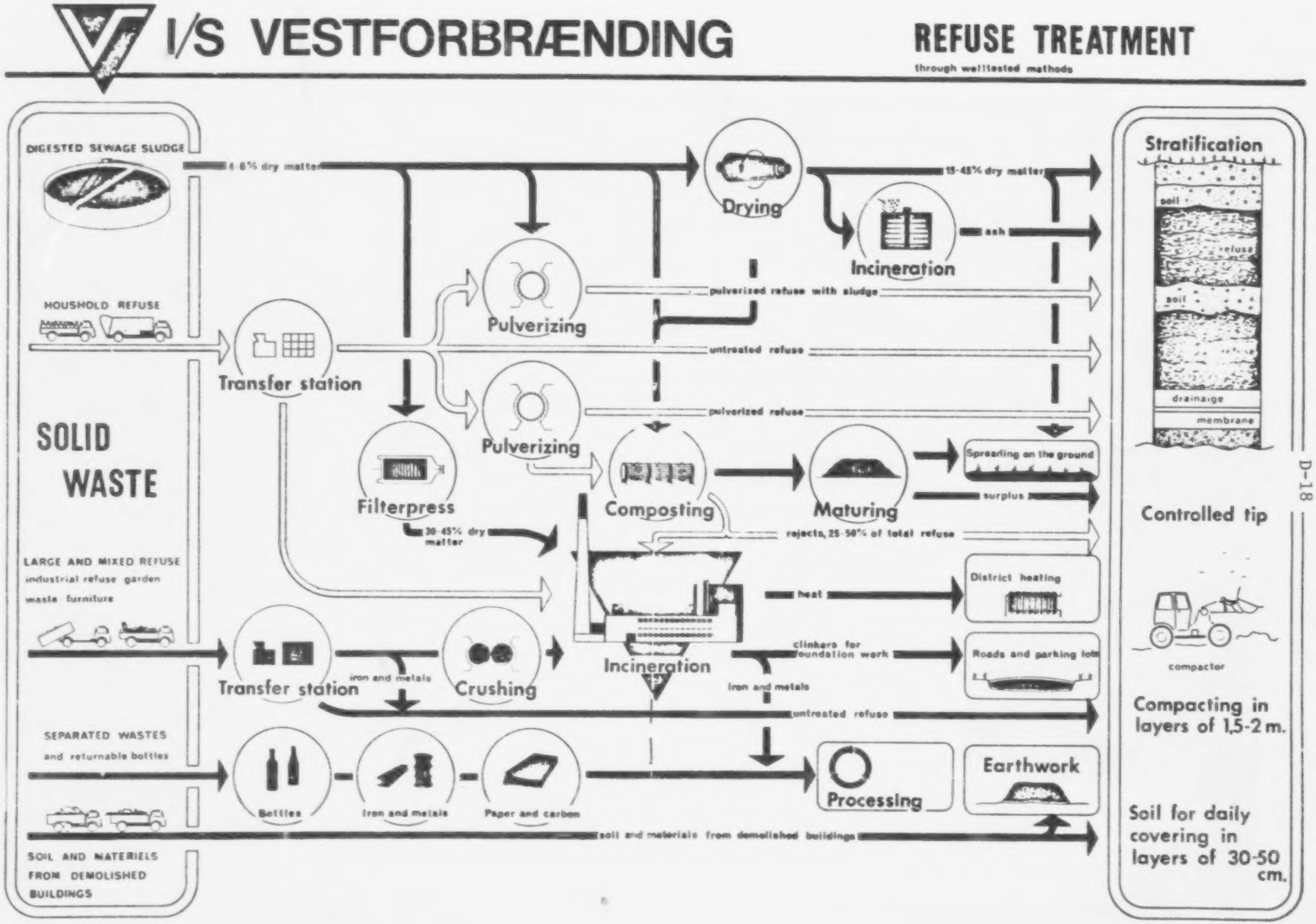

I/S VESTFORBRÆNDING
REFUSE TREATMENT
through welltested methods
SOLID WASTE
DIGESTED SEWAGE SLUDGE
HOUSHOLD REFUSE
LARGE AND MIXED REFUSE industrial refuse garden waste furniture
SEPARATED WASTES and returnable bottles
SOIL AND MATERIELS FROM DEMOLISHED BUILDINGS
4-6% dry matter
Transfer station
Pulverizing
Pulverizing
Filterpress
30-45% dry matter
Drying
15-45% dry matter
Incineration
ash
pulverized refuse with sludge
untreated refuse
pulverized refuse
Composting
Maturing
Spreading on the ground
surplus
rejects, 25-50% of total refuse
District heating
heat
clinkers for foundation work
Roads and parking lots
Incineration
iron and metals
Transfer station
iron and metals
Crushing
untreated refuse
Bottles
Iron and metals
Paper and carbon
Processing
Earthwork
soil and materials from demolished buildings
Stratification
soil
refuse
soil
refuse
drainaige
membrane
Controlled tip
compactor
Compacting in layers of 1,5-2 m.
Soil for daily covering in layers of 30-50 cm.

FIGURE D-12. WASTE STREAMS AND THEIR TREATMENT OPTIONS IN COPENHAGEN AND ITS WESTERN SUBURBS

REFUSE COLLECTION AND TRANSFER STATIONS

General Comments on Collection

The European pattern of collection and transfer has many similarities to that of North America. Generally speaking, there is more collection by the public sector, occasional labor representation in management functions, occasional computerized systems for physical control and fiscal billing. The homeowner cost assessment methods are quite varied.

Household Containers

There is a clear trend away from the open top metal refuse container in favor of rubber, plastic or paper containers (see Table E-1). An integrated program of collecting truck purchase along with purchase of standardized rubber or plastic containers was observed several times in Central Europe. Several other systems used standard sized paper sacks that could be collected by a flat bed truck rather than a compactor truck. Other systems use polyethelene or polyvinyl chloride (PVC) sacks. Most high quality steam production facilities discourage PVC due to the corrosive effects.

Collecting Organization

Table E-2 presents data showing the extent of public and private collection. Generally speaking, there is more public collection. However, as in the U.S. this varies widely from city to city.

Consistent with European governments being more socially conscious, many public collecting organizations permit representatives from labor to participate in management functions. This, in part, has contributed to the success of two industrial engineered collector control and payment incentive systems at Hamburg and Copenhagen: Amager.

Collection Costs

Worldwide, collection cost are 70 to 90 percent of the total cost of collection and disposal. Most of the respondents gave figure (Table E-3) on the total because that is the amount billed to citizens and thus the better known figure.

Costs range from $25 to $90 per year per household as a solid waste management charge to the citizens.

TABLE E-1. HOUSEHOLD REFUSE CONTAINERS

Trip		
1	Werdenberg-Liechtenstein	
2	Baden-Brugg	
3	Duesseldorf	
4	Wuppertal	Rubber
5	Krefeld	
6	Paris:Issy	
7	Hamburg:Stellinger-Moor	Rubber
8	Zurich:Hagenholz	Plastic and Paper Sacks
9	The Hague	
10	Dieppe	Open steel cans were replaced with PUC Sacks in October 1977
11	Gothenburg	
12	Uppsala	Plastic sacks
13	Horsens	Paper Sacks (purchased by homeowners)
14	Copenhagen:Amager	
15	Copenhagen:West	

TABLE E-2. REFUSE COLLECTION

Trip		Number of Trucks			
		Public	Private Haulers	Other Cities	Industries
1	Werdenberg-Liechtenstein		8		Several
2	Baden-Brugg	60	40		
3	Duesseldorf				
4	Wuppertal				
5	Krefeld				
6	Paris:Issy	750 to four Paris plants			
7	Hamburg:Stellinger-Moor	195 for Public Household Refuse 30 for Public Bulky Trash			
8	Zurich:Hagenholz	130(56%)	(26%)	(18%)	
9	The Hague	55	many	many	
10	Dieppe (and Deauville)	8 for Public Household Refuse 3 for Public Bulky Trash			
11	Gothenburg	30 large Public Transfer track-trailers 100 other Public and Private tracks			
12	Uppsala	25			
13	Horsens				
14	Copenhagen:Amager				
15	Copenhagen:West				

TABLE E-3. COLLECTION COSTS AND ASSESSMENT METHOD

Trip		Collection Costs Only	Collection and Disposal Costs Together	Conversion to 1977 U.S. Dollars	Assessemnt Method
1	Werdenberg-Liechtenstein		One family pays 90 S.F.r/year	($45)	Plant assesses community based of origin of truck weighed
2	Baden-Brugg	50 to 85 S.Fr. /year		($25-43)	The 28 communities assess family
3	Duesseldorf				
4	Wuppertal				
5	Krefeld				Container rental
6	Paris:Issy		350 F.Fr.	($74)	Proportional to real estate taxes
7	Hamburg: Stellinger-Moor	3.46 D.M. per week per 1110-liter (gallon) container		($90)* per container-year	Container rental
8	Zurich:Hagenholz				
9	The Hague				
10	Dieppe				
11	Gothenburg				Proportional to metered water service
12	Uppsala				
13	Horsens				
14	Copenhogen: Amager		465 S.Kr./year	($80)	Sale of paper sacks
15	Copenhagen: West		420 S.Kr./year	($72)	Computerized system using container size, steps, stairs

* The figure not only includes collection and disposal costs but also the purchase of containers and specially equipped trucks.

Assessment Methods

The methods for assessing collection (and disposal) costs vary widely. Some systems serve so many cities that a clear assessment pattern was not available. The Hamburg and Wuppertal plants obtain revenue from household rental of standardized rubber containers. At Horsens, paper sacks are purchased by homeowners. Paris assesses solid waste costs in proportion to real estate taxes. Dieppe, however, assesses in proportion to metered water service.

Probably the most accurate assessment comes from Renholdnings Selskabet (Society for Waste Collection) in Copenhagen. Charges are set based on container volume, steps walked and stairs.

Vehicles

European vehicles, generally,have similar features, options and size ranges as in the U.S. However, due to smaller and winding streets, the size distribution is different and results in a smaller averaage size. Paris uses a few electric trucks as later explained. Gothenburg uses cylindrical transfer trailers not seen in America (see Figure E-1).

Collecting Times

Trucks make one to four trips per day depending on geography, average haul distance, and labor agreements (see Table E-4). Official hours are often 8 per day. However, many actually work only 5, 6 or 7 hours per day. In Paris, workers collect refuse for about 4 hours and then sweep city streets for another 4 hours.

Most workers collect 5 days per week. Some private haulers collect 5 1/2 days. Paris provides 7 day per week pickup of restaurant garbage.

Homeowners have their refuse picked up once or twice per week.

Homeowner Deliveries

Many plants place detachable containers near the entrance to the facility so that cars, trailers, pick up trucks, etc, can off-load without interrupting larger vehicle deliveries.

Collection Activity Effecting Resource Recovery

Some refuse burning facilities will only take household refuse. Refuse burning and energy production is greatly simplified if high calorie-containing industrial and bulky waste is excluded.

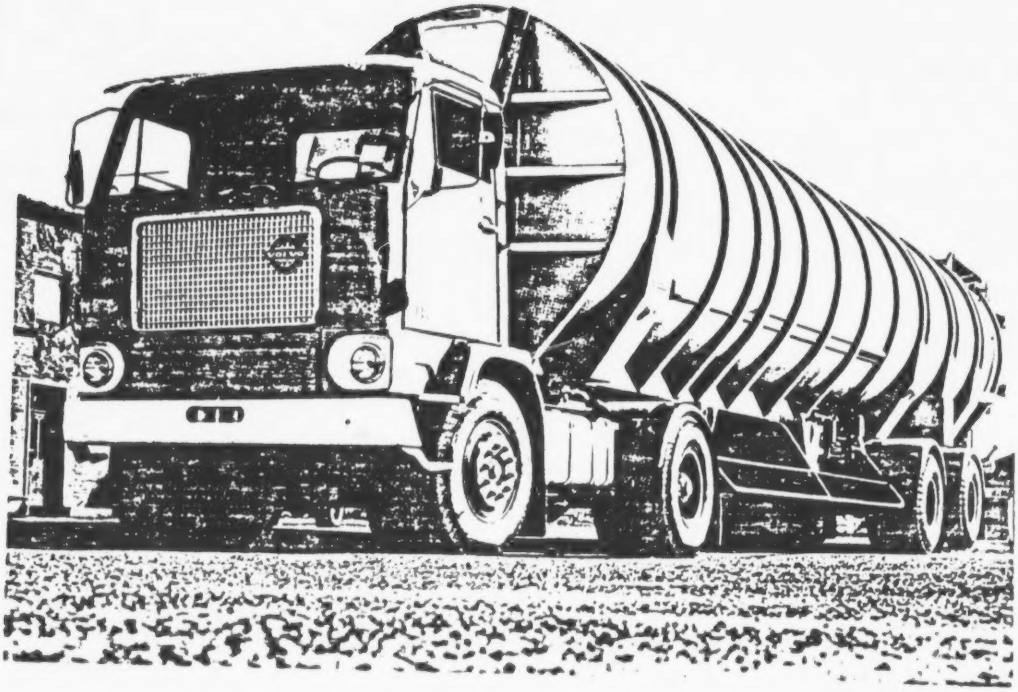


FIGURE E-1. TRANSFER VEHICLE. THE CYLINDRICAL CHAMBER HOLDS ABOUT 50 m^3(1,765 ft^3) COMPRESSED AT THE TRANSFER STATION BY A FACTOR OF ABOUT 3.3 to 1. (Courtesy GRAAB)

TABLE E-4. COLLECTING TIMES

Trip		Trips/Day	Hours/Day	Days/Week	Hours/Week	Collections/Week
1	Werdenberg-Liechtenstein	2-4	8	5	40	
2	Baden-Brugg		8	5	40	
3	Duesseldorf		Public 7	5	35	1
4	Wuppertal		Private 8	5 1/2	44	
5	Krefeld					
6	Paris:Issy		Public 6 to 8 a.m. delivery Private 9 to 12 p.m. delivery	7 5		
7	Hamburg:Stellinger-Moor					
8	Zurich:Hagenholz	4				
9	The Hague					2
10	Dieppe (and Deauville)					2
11	Gothenburg			5		
12	Uppsala		8	5	40	
13	Horsens					
14	Copenhagen:Amager					
15	Copenhagen:West					

However, the plant manager and staff may have to put forth the extra effort because incineration is the proper disposal alternative and/or because the energy from this waste.

Transfer Stations

Transfer stations are increasingly popular in Europe as (1) economies of scale require more waste to be consumed at one location and (2) there is a desire to reduce highway travel time and collection costs.

In Paris, Ramainville, one of the original four refuse burners was converted to a transfer station. Refuse is transferred to Issy for combustion.

At Gothenburg, five transfer stations comact and 30 trailers bring refuse to the Savenas refuse fired steam generator.

Copenhagen: Amager's concept is quite different. This transfer station is located next to the refuse burner. Both are located near the populated downtown. Bulky combustibles are shredded and transferred 330 meters (100 yards) to the refuse burner. Noncombustible waste is simply transferred to a distant landfill.

There are plans at Uppsala to put a transfer station in a distant city so that more energy containing waste can be gathered and converted to needed district heating hot water at Uppsala.

The authors were intrigued to see an industrial hazardous waste transfer station in Horsens that collects material for transport to Nyborg, Denmark. A brochure is reprinted in the Appendix. The Danes are leaders in regional government hazardous waste collection and controlled disposal.

Because Europeans furnace grates are not designed for shredded material, there is only a moderate amount of shredding prior to landfill. In 1977, there were no continental European transfer stations preparing shredded RDF for 100 percent RDF firing or co-firing, i.e. only mass burning is practiced.

Specific System Comments on Collection

Werdenberg-Liechtenstein

Throughout the region, trucks of various sizes and descriptions collect waste material. The Society for Refuse Management licenses four private companies to collect waste materials from households. The eight trucks owned by these four firms make two to four trips per day. Truck sizes range from 12 to 15m3 (15.7 to 19.6 cubic yds). In addition, there are a few commercial private haulers and several industrial companies with their own trucks. Most are active 8 hours per day - 5 days per week.

Three of the collection firms are paid by the Society and one is paid by his local community. All are paid on a price per ton basis as weighed on the plant scales.

Costs are distributed back to the communities based on a careful accounting of where the wastes comes from. Fees have been relatively constant over the last three to four years.

Each household pays taxes to his respective community. As an example, the plant manager pays 90 Swiss francs per year for his waste to be collected and disposed.

The rise in total collections from 4,000 tonnes (4,409 tons) in 1962 to 24,000 tonnes (26,455 tons) in 1973 must be interpreted carefully. First, these are collection rates and not generation rates. In other words, there are fewer people throwing refuse over the hill and more providing waste to collectors. Secondly, the local refuse collection company has been expanding its geographic territory as more communities decide to join. Neither an influx of people nor increased waste generation rates could have contributed to the dramatic increase in household collections. There has been a fall in industrial pickups which coincides with the European and especially the Swiss recession.

Baden-Brugg

About 60 public and 40 private collection vehicles bring refuse to the plant 8 hours per day, 5 days per week. Each community is charged for the weight delivered by its trucks. Each family served pays 50-85 S.Fr. ($20-34) per year for collection.

Wuppertal

Public collection vehicles collect household refuse once per week and deliver it to the plant 7 hours per day, 5 days per week. Private vehicles handling primarily commercial and industrial waste deliver to the plant 8 hours per day, 5-1/2 days per week.

Citizens with automobiles coming to the plant must dump into special containers for that purpose which are later picked up and emptied into the pit. Citizen dumping directly into pits is prohibited.

Each household served in 1976 paid an annual fee of 230 D.M. ($97.33) for each 110 liter (29 gallon) standard rubber container (usually one per family). They are emptied once per week.

Paris:Issy

Refuse is collected in standard refuse collection trucks. However, some material is received at Issy in 30m3 (40 yd3) transfer trailers from Romanville, the transfer station in northeast Paris.

Paris has 750 trucks bringing refuse to all four plants. Of these, 180 are electric. Forty are only 6 or 8m3 (8 or 10 yd3) for collecting on narrow streets. Most, however, are 16 m3 (20 yd3) traditional European garbage trucks.

The electric trucks mentioned above can travel 50 km (30 miles) on a charge. A typical route is 5 km (3 miles) while the typical distance to unload and return to the garage is 15 km (9 miles). Thus the truck must be recharged about every two runs.

The schedule of collection is rather unique. The City of Paris public vehicles deliver to Issy between 6 and 8 a.m.; seven (7) days per week. These same public workers spend the remainder of the working day weeping the streets in their assigned neighborhoods. Suburban and private vehicles deliver between 9 a.m. and noon.

Of the 5,000 collection workers, 70 percent are foreign; many being from Senegal, Algeria and other parts of Africa. There have been increasing numbers of French workers in recent years.

Each of the 55 communities is responsible for its respective collection. The cities either publicly collect or license private haulers. The City of Paris publicly collects its residential and commercial waste but subcontracts its truck fleet maintenance to a private firm.

The collection fees in most communities are assessed proportionally to real estate taxes once the year's financial results are declared and accepted. The typical household collection and disposal fee would be about 350 F.fr./tonne ($24/ton). The collection costs had been rising 15 percent per year but rose only 5 percent last year.

Hamburg:Stellinger-Moor

Both public and private organizations collect waste in the metropolitan area as follows:

City of Hamburg, house waste publicly collected	4,435,603 tonnes
Suburbs publicly and privately collected	448,278
Industrial waste privately collected	575,231
	5,459,112 tonnes

Local officials are using Oscar of "Sesame Street" to urge people to put all of the trash into the garbage cans and to not spill trash onto the ground (See Figure E-2).

The city of Hamburg has developed an industrial engineered computer based system to specify routes to pay workers and collect disposal fees. Points are awarded and fees are charged based on location of the container (backyard, upstairs, curb, etc.), distance walked and container volume. The system begun in 1964, was developed along with the local union.

For those interested in details, a German language 44 page report exists that outlines the program, prices and results.* A similar program is described in greater detail in the Copenhagen trip report.

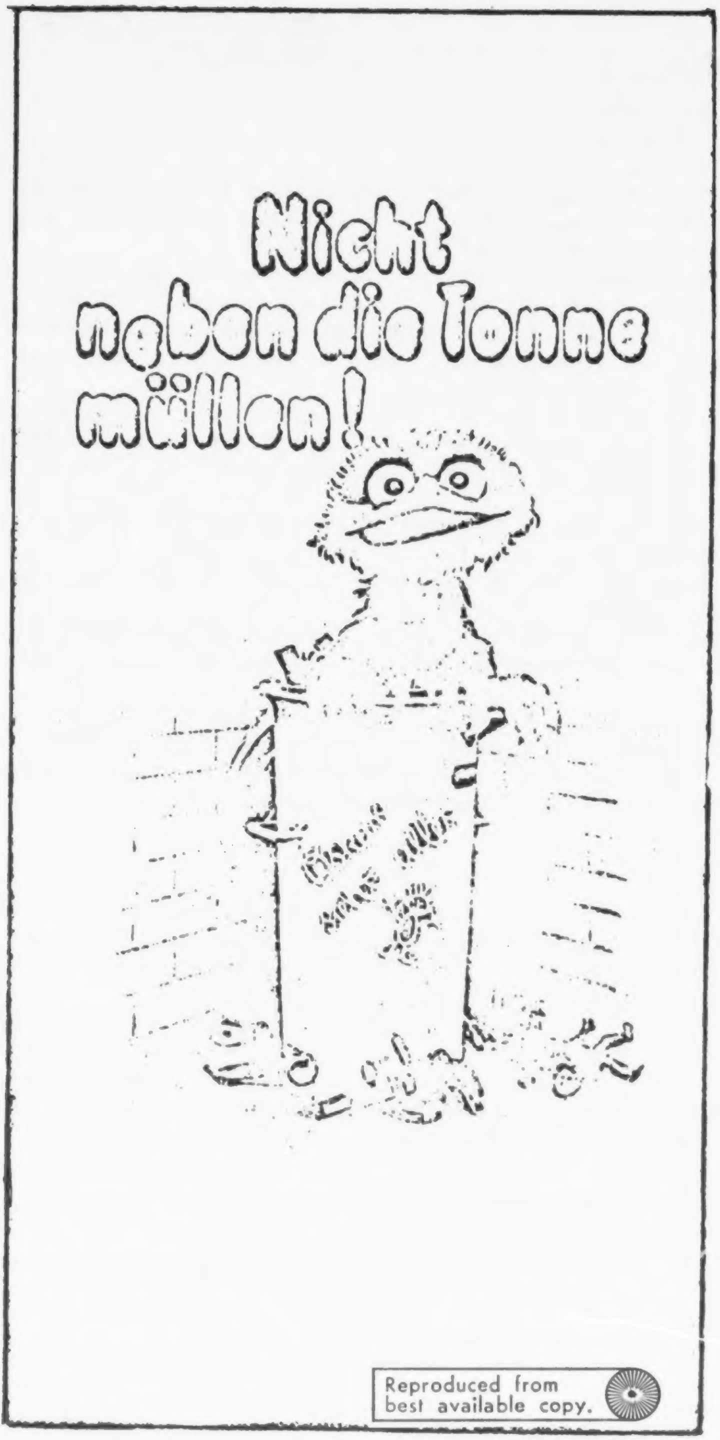
An example of the point system for collection workers follows: Points for the transportation by a waste collector for a 110 liter (29 gallon) waste container.

(a) 30 points for level ground transport up to
22 points for walking 15 meters (49 feet)
8 points for tipping into truck

(b) 50 points for transport up or down steps
22 points for walking 15 meters (49 feet)
20 points for steps
8 points for tipping into truck

(c) 110 points for transport up or down steps over 50 meters (163 feet).

Points are accumulated over a month duration and the workers are paid a varying amount per 100 points as shown below:


Nicht
neben die Tonne
müllen!

Reproduced from
best available copy.

Figure E-2. Public Relations Cartoon of Oscar (of Sesame Street) Encouraging people to put all trash in the containers

Point Range	Price Paid to Worker per 100 Points	
	Deutsch Mark	Dollars
From 3,601 to 6,400	.33	0.14
From 5,401 to 9,500	.58	0.24
From 9,501 and above	.29	0.12

The point system clearly penalizes both the under and the over producer. There likely was concern about the long-term health and safety of collectors who worked too hard and long.

The homeowner's cost of garbage removal is essentially determined by the size bins used, distance and the presence of stairs. The price is lower per liter if larger receptacles are used. However, because of architectural and other reasons, this is not always possible. In 1976, the city used:

- 770/1100 liter (203/290 gallons) bulk containers--37,106
- 110/220 liter (29/58 gallons) house bins--304,862
- 35/55 liter (9.2/14.5 gallons) dwelling bins--47,933.

An average of 7.3 liters of domestic refuse was produced daily during 1976 by each inhabitant.

A typical family will pay 3.46 DM ($1.40) per week for rent of a 110-liter container.

The City of Hamburg spent 95,486,000 DM ($45,361,000) on waste collection and transport in 1976. This converts to 17.49 DM per cubic meter.

During 1976, 1,417 laborers were employed in garbage removal. For this they needed 195 trucks for house refuse and 30 trucks for large refuse. As part of the collection workers' contract, foreign workers are limited to no more than 10 percent of the work force.

Zurich:Hagenholz

Solid waste collection is performed by the City of Zurich, Department of Streets and Sanitation (Abfuhrwesen), by private collectors and by other communities. The 130 Abfuhrwesen vehicles typically make four trips per day carrying about five tons per truck.

Beginning in 1070, Abfuhrwesen began using plastic and paper sacks in place of metal containers. This has had a very positive effect on reducing collection personnel and hence costs. Considering only the solid waste, the collection activities were performed in 1976 by the three types of collectors in the following manner:

Abfuhrwesen (city of Zurich)	56
Other Municipalities	18
Private haulers and businesses	26
	100% by weight

The Hague

There are 55 municipal packer trucks which collect twice per week on weekdays except Wednesday when the crews are assigned to bulky refuse pickup. They do this in two alternate sections of town on alternate Wednesdays, using open trucks.

Private haulers also deliver refuse to a separate bunker and pay cash for the privilege on a weight basis. If a load is mostly metallic, such as appliances, it is placed in a collection yard at the plant for later procesing by a private operator. See the previous section on "Front-End Processing".

Dieppe

For the Dieppe area, there are eight city collection trucks plus three small open trucks which, until October 1, 1977, collected daily, 6 days per week. After October 1, 1977, collections were to be every 2 days. Other suburbs also send in truck loads irregularly. On Sunday mornings special collections are made from restaurants. The past practice of picking up and dumping open bins at the collection point was to have been replaced October 1,1977 by use of polyvinylchloride bags provided by the city.

Each household and business receives a separate charge on their tax bill for refuse and sewage service which is based at their metered water consumption.

No bulky refuse is accepted at Dieppe larger than 1 meter (3.3 ft).

Gothenburg

In 1971, the GRAAB organization established the first of five transfer stations and began acquiring specially-built transfer trucks as shown in Figure E-1. The cyclindrical chamber is 13.60 m (44.6 ft) long and .5 m(8.2 ft) in diameter, volume is 50 m^3 (538 ft^3), and overall height is 3.83 m (12.5 ft). Total weight is 33.40 tonnes (36.7 tons). Carrying capacity is 17.40 tonnes (19.1 tons). Overall length, including tractor, is 15.86 m (52 ft).

There are 30 of these transfer vehicles in the system bringing refuse to the plant from the five transfer stations. In 1972, each vehicle cost 250,000 S.Kr. ($62,500). Also, over 100 other trucks deliver directly to the Savenas plant. Total collections and deliveries to the transfer stations are made by trucks in the individual districts. There are about 300 truck loads per day delivered between 7:00 a.m. and 3:00 p.m., 5 days/week.

Figure E-3 shows one transfer station. The lower view shows two compactor trucks and one industrial truck delivering simultaneously to two hoppers. One of the two transfer trailers has a truck cab attached.

Mr. Bengt Rundqwist, Works Director, described the operation of the system in a leaflet prepared for visitors in 1972:

> "The transfer stations are as centrally positioned as possible within each generation area in relation to local transport, since this method generally requires short distances for good economy. The central position requires high operational reliability to prevent health hazards. For the stations further away from the

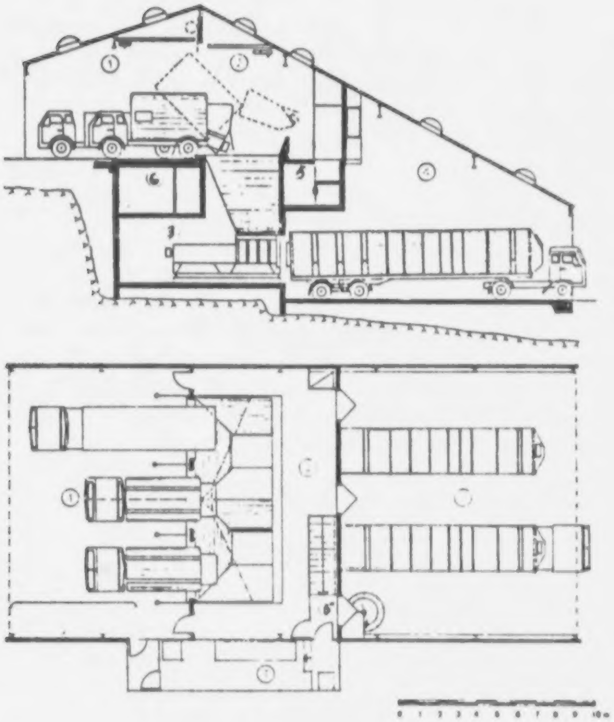


FIGURE E-3. CROSS SECTION AND PLAN VIEW OF TRANSFER STATION. (Courtesy GRAAB)

1. Tipping Hall
2. Bunker
3. Compactor
4. Vehicle Hall
5. Stairway
6. Washroom
7. Control Room

incineration plant, this means that irrespective of capacity requirements these are designed with double compressors, whilst the other stations are constructed as single stations.

"The waste is received basically in the same way and with the same type of weighing instruments and equipment as the main plant. However, only one scale is provided. This is why, in tare weighing, the vehicles must drive over the same scale another time when leaving."

" Referring again to Figure E-3, after weighing incoming refuse, the vehicles are backed into the emptying bay (1). The refuse is dumped into a funnel-shaped bunker with two hoppers (2). Two compactors operate under the bunker in the compactor room (3). In the unloading bay (4), transfer trailers are coupled to the compactors, which force the refuse into the trailer containers against counter pressure. In the control room (7), a good view is obtained of the unloading and loading operations. From here, everything happening inside and outside the plant can be monitored. A station equipped with two compressors has a capacity of about 50,000 tons/year and costs about 2 million S.Kr. ($428,266)."

" The transfer trailer is equipped with a hydraulic plate which, when loading, serves as back-stop to obtain correct load distribution and compression ratios (about 1:3). On emptying--which takes 4 to 5 minutes--the plate serves as an explusion plate."

Uppsala

The city street administration operates approximately 25 collection vehicles of 2 to 3 tonne capacity each which collect 5 days per week, once per week from each residence. Plastic bags are used which are generally deposited by the householder beneath some shelter to minimize moisture pickup and snow accumulation. The trucks operate from 6:30 a.m. to 3:00 p.m. although their routes are generally completed by 1:00 p.m. The plant receives about 200 tonnes (220 tons) per day.

Copenhagen:Amager

Delivery is by local garbage trucks. There is little, if any, bulky waste burned directly.

The overall cost for collection and disposal averages about 465 D.Kr. per year per person ($80.48).

Waste has been collected since 1898 by a not-for-profit society, Renholdnings Selskabet. Much could be written regarding this very successful organization. One item of interest is that each walking collector has a computer printout that tells him exactly how many Danish Kroner he will earn by "traveling 17 horizontal steps, three vertical steps, picking up a 10 liter (can gallon)...".

Comment: We are unaware of any collection system as detailed and filled with motivational factors as the system at Rehnoldnings. Further information is available.

A large transfer station at Amager is shown under construction in 1977 in Figure D-1. The area's industrial waste and household bulky waste is taken to this transfer station located on the grounds of the Amager plant. Some of the waste is then transferred to the Uggelose landfill located 37 km (23 mi) northwest of Amager and inland. During 1975-1976, 32,374 garbage trucks entered the transfer station. Some shredded combustible waste was taken to the adjoining refuse burning plant to be mixed with other raw refuse prior to "mass burning". About 13,723 transfer trailer loads were taken to the Uggelose landfill.

Copenhagen:West

In addition to the normal input from local garbage trucks, large transfer trailers from the city of Hillerod travel about 40 km (25 miles) one-way to bring northern waste to the Copenhagen:West unit. Copenhagen: West does not have a transfer station.

The overall cost for collection and disposal averages about 420 D.Kr. per year per person ($72.69).

COMPOSITION OF REFUSE

The composition of refuse is described in these following ways in the below sections:

- Physical (paper, glass, etc.)
- Moisture (% H_2O)
- Chemical, Elemental and Molecular (C, Volatiles, Ash. etc.)

Physical Composition of Refuse

Several refuse compositions collected from the visited plants are presented in Table F-1. Because the percentages vary so extremely from place to place and from time to time, no European composite has been developed. Only with the addition of several more table samples should this be attempted. The reader is thus referred to Table F-2 (Zurich, Geneva, U.S.A., London, and Birmingham), Table F-3 (Hamburg) and Table F-4 (Thun outside of Zurich).

Moisture Content

Table F-5 presents moisture percentages in refuse that is combusted where the information was available. In this sampling, the moisture percent ranged from a low average of 22.5% to a high average of 32.5%. The average among six (6) facilities was 27.1%.

At two times during 1975 at Dieppe, France; Thermical-INOR the local plant owner contracted for detailed composition studies to be made. Results are shown in Table H-5. Moisture per separable item is shown ranging from 3.2% associated with the glass fraction in December compared with 83.6% in putrescibles in February. With one minor exception all categories show higher moisture readings in February. Obviously the weighted average moisture content of 38.9% in February was caused by rain during the previous days. Even the 32.3% average in December is higher than the European average.

Chemical, Elemental and Molecular Composition of Refuse

Data of this nature is rare. However, Table F-6 is shown to represent one reading of Zurich. In this analysis water is 33%, organic material is 41% and minerals account for 26%

A much earlier study used to design the Copenhagen:West incinerator was the 1964-65 analysis of composition by sources as shown in Table F-7. Separate analyses were made for samples from (1) a shopping area, (2) a villa housing area, (3) a new housing area and (4) an industrial area. The low readings of the "higher heating value" should warn the reader that today's waste is substantially different in composition.

TABLE F-1. MOISTURE PERCENTAGES IN REFUSE COMBUSTED IN VISITED EUROPEAN REFUSE-TO-ENERGY PLANTS

Trip		Percent Moisture		
		Low	Average	High
1	Werdenberg-Liechtenstein	25.0	35.0	40.0
2	Baden-Brugg	--	--	--
3	Duesseldorf	--	--	--
4	Wuppertal	--	--	--
5	Krefeld	--	20.0	--
6	Paris:Issy	--	--	--
7	Hamburg:Stellinger-Moor	--	30.0	--
8	Zurich:Hagenholz	20.0	22.5	25.0
	Switzerland Average	--	32.9	--
9	The Hague	32.3	--	38.9
10	Dieepe (and Deauville)	--	23.0	--
11	Goteborg	--	--	--
12	Uppsala	--	--	--
13	Horsens	--	--	--
14	Copenhagen:Amager	--	32.0	--
15	Copenhagen:West	31.1	--	37.5
	Average	22.5	27.9	32.5

Source: Battelle interviews

TABLE F-2. COMPOSITION OF MUNICIPAL SOLID WASTE IN SWITZERLAND, USA, AND BRITAIN

Constituants	Composition by Weight Percent (%) (Location and Source)						
	Switzerland			U.S.A.		Britain	
	1	2	3	1	4	5	6
Food waste	20	12	14.5	6	14	26	13
Textiles	4	2.5	3.0	3	-	2	2.5
Paper	36	30	33.5	40	55	37	51.5
Plastics	4	7	2	4	1	1.5	1.0
Leather and rubber	2	-	-	2	-	-	-
Wood	4	6	2.5	2	4	-	-
Glass	8	5	8.5	17	9	8	6.5
Ferrous and nonferrous metals	6	7	5	9	9	8.5	6.5
Street sweepings and garden waste	6	-	-	5	5	2	3
Stones, dust, and other debris	10	33.5	31	12	3	15	16

Sources:
1. National averages as published by EAWAG (1971) (used for planning Hagenholz)
2. Municipal solid waste of Geneva (1972)
3. Municipal solid waste of Zurich (1963/1964)
4. Reference
5. London (1972)
6. Birmingham (1972)

TABLE F-3. COMPOSITION OF MUNICIPAL WASTE AT HAMBURG:STELLINGER-MOOR

	Weight (%)[a]			Volume (%)			Heating Value Kcal/kg	
	1974	1975	1976	1974	1975	1976	Kcal/kg Individual Component[b]	Kcal/kg of Mixed Waste[c]
Glass	15.1	22.7	22.9	5.5	14.5	14.4		
Stone, ceramic	2.1	2.0	0.8	0.7	1.0	0.3		
Metal	4.1	4.5	5.3	6.0	7.0	7.3		
Paper	23.9	17.7	24.4	26.1	22.1	28.6	3500	854
Pasteboard, wood	9.1	5.4	5.0	20.3	13.7	12.7	3500	175
Textile, leather, rubber	2.6	3.7	1.4	2.6	4.3	1.6	4000	56
Vegetables	35.2	30.0	29.0	20.2	17.6	16.8	800	232
Plastic*	5.5	4.6	5.0	17.9	13.9	14.7	9400	470
Ash, others	2.4	9.4	6.2	0.7	5.9	3.6		
	100.0	100.0	100.0	100.0	100.0	100.0		1800

---

*PVC comprises 0.6 percent of the waste.

Sample of 2.521 tonnes of municipal waste
equalling 23.1 cubic meters
resulting in 0.11 tonnes per cubic meter as the specific density-110 kg/cubic meters (242 pounds/cubic meter).

Formula C = a x b

Source: City of Hamburg, 1975 and 1976 annual reports (March 1, 1976).

TABLE F-4. REFUSE COMPOSITION AT THUN, 1975

Paper	39.66%
Glass	8.31%
Ceramic	1.23%
Metal	4.80%
Wood	5.51%
Textiles, Leather, Rubber	6.04%
Plastics	6,57%
Kitchen waste	8,96%
Garden waste	13,42%
Misc.	5,50%

(From Wohin mit den Abfallen?" Zurich, November 1976)

TABLE F-5. APPROXIMATE COMPOSITION OF TWO SAMPLES OF REFUSE RECEIVED AT DIEPPE IN 1975 COURTESY OF THERMICAL-INOR)

	Sample for February 3, 1975		Sample for December 4, 1975	
	Weight, Percent	Moisture, Percent	Weight, Percent	Moisture, Percent
Fines, Unidentified Pieces smaller than 2 mm	25.30	41.1	31.90	16.7
Paper Cartons	5.97	25.9	9.90	15.2
Cloth	0.20	44.5	0.90	28.1
Plastics	3.50	11.2	1.20	9.8
Bones	0.65	15.6	0.45	15.4
Metal	4.60	3.8	2.90	3.7
Glass	9.85	5.1	5.20	3.2
Unclassified Combustibles	4.25	13.4	2.70	18.3
Unclassified Inerts	17.22	8.0	15.20	6.1
Putrescibles	28.46	83.6	29.65	78.8
Weighted Average		38.9		32.3

TABLE F-6. AVERAGE CHEMICAL COMPOSITION OF MUNICIPAL SOLID WASTE IN ZURICH, SWITZERLAND

Constituent	Composition in Weight[a] Component	Subtotal
Water		32.9
Material Containing Organics		
Decomposable Material	36.20	
Carbon	20.20	
Hydrogen	2.60	
Chlorine	0.34	
Nitrogen	0.57	
Phosphorous	0.12	
Organic Material Total		41.0
Material Containing Minerals		
Carbonate	0.86	
Potassium	0.11	
Calcium	2.40	
Sodium	0.54	
Magnesium	0.24	
Ferrous	2.35	
Mineral Material Total		26.1
GRAND TOTAL		100.0

(a) The table is not composed for totals to be summed.

TABLE F-7. WEST INCINERATOR OF COPENHAGEN REFUSE ANALYSIS

	Percent	Moisture	Combust- ibles	Ash	Volatiles	Fixed C	HHV kcal/kg
			April 9, 1964				
Shopping Area	10	2.96	4.54	2.50	3.88	0.65	186.40
Villa Housing Area	34	10.06	14.68	9.25	11.24	3.45	528.76
New Housing Area	27	7.73	12.47	6.80	10.83	1.64	485.73
Industrial Area	29	10.35	9.27	9.39	7.69	1.58	366.56
Total Average	100	31.10	40.96	27.94	33.64	7.32	1621.45
			January 14, 1965				
Shopping Area	10	3.18	4.06	2.77	3.47	0.58	166.90
Villa Housing Area	34	13.86	11.63	8.51	10.37	1.26	453.56
New Housing Area	27	9.07	12.60	5.33	10.94	1.66	511.38
Industrial Area	29	11.40	9.40	8.19	8.15	1.26	338.14
Total Average	100	37.51	37.69	24.80	32.93	4.76	1469.98

HEATING VALUE OF REFUSE

Definitions and Calculations

Heating values are expressed in either of two manners (1) Lower Heating Value (LHV) and (2) Higher Heating Value (HHV). This has occassionally lead to confusion even through the difference is only about 7%. The Europeans have the practice of using Lower Heat Value (LHV) versus the U.S. practice of using Higher Heat Value (HHV). The difference arises from the heat of condensation of the hydrogen-produced water in the flue gas.

Heating values cannot be calculated precisely. Usually they are measured by burning a fuel sample in oxygen in a bomb calorimeter. The heat released and measured in the calorimeter includes that heat given up when the water vapor formed by the burning of hydrogen in the fuel, condenses, giving up its heat of vaporization (1052.8 Btu/lb) (584.9 Kcal/Kg)(139.7 kJ/Kg). Thus the calorimeter usually measures the Higher Heat Value. In Europe the well established practice is to calculate the Lower Heat Value by substracting the heat of condensation of the hydrogen-produced water from the calorimeter-measured heat value.

With hydrogen-free fuel such as pure carbon, the HHV and LHV are identical. As the hydrogen content of fuel increases the discrepancy widens. Lowry(1), in his Chemistry of Coal Utilization, provides data as shown in Table G-1.

This difference has no effect in efficiency calculations. In Europe the heat of condensation is not included in the heat input so it doesn't appear in the efficiency calculations. In the U.S. it is a part of the heat. However,in calculation of efficiency it is always subtracted from output as a heat loss of about 7 percent due to energy lost up the stack in uncondensed water vapor that was formed in combustion.

The hydrogen content of refuse is highly variable. Kaiser (2) assumed an average of 3.5 percent by weight. Perry (3) provides a simple conversion formula:

$$LVH = HHV - 92.7\ H.$$

Thus for a refuse having an LHV of 2500 Kcal/Kg (4500 Btu/lb) (597.1 kJ/Kg), the HHV in Btu/lb is

$$\begin{aligned} HHV &= 4500 + 92.7\ (3.5) \\ &= 4500 + 324 \\ &= 4824\ \text{Btu/lb.} \end{aligned}$$

Thus in this typical example the HHV is 7.2 percent higher than the LHV.

For the three units of measurement, the formulas are slightly different as follows:

HHV (Btu/lb) = LHV + 324
HHV (Kcal/Kg) = LHV + 180
HHV (KJ/Kg) = HHV + 43

TABLE G-1. HYDROGEN CONTENT AND CALORIFIC VALUES OF FOUR FUELS

	Hydrogen (H_2) percent	Calorific Values, Btu/lb		Heat Lost in Water Vapor at 20 C, percent
		Gross (HHV)	Net (LHV)	
Coke	0.30	12,500	12,470	0.2
Anthracite	2.50	12,780	12,545	1.8
Bituminous Coal	5.18	13,560	13,075	3.6
Petroleum	12.75	18,540	17,345	6.4

Source: Lowry, H. H., "Chemistry of Coal Utilization", First Edition, Vol. 1, page 134, Table 1.

Refers also to: Kaiser, E.R., Proceedings, 1964 ASME Incinerator Conference, p. 36.

and to: Perry, Chemical Engineers Handbook, Fifth Edition, p. 914.

General Comments on Refuse Heating Values

Figure G-1 shows how the lower heating values have risen over the years in ten (10) European cities. Generally speaking, most of the visited plants have current values between those of Duesseldorf on the low side and Stockkholm on the high side.

Table G-2 presents LHV's as reported for most of the 15 visited plants. In several instances the actual LHV has been higher than that used in the plant design.

In each case the difference can be traced to the amount and type of industrial waste now being imputed to the system as opposes to that originally anticipated. This has resulted in very high maintenance costs.

Specific Comments on Systems' Heating Values

Werdenberg-Liechtenstein

At Werdenberg-Liechtenstein, there have been magnesium chips from the Hilti fastener-explosives plant, and industrial trimmings from a screen printing firm, a plastic tape manufacturer and a leather shoe manufacturer. Such materials have occassionally caused hot spots on the grates adversly affecting bar life.

Duesseldorf

At Duesseldorf, the original "Duesseldorf Walzenrost Roller Grate" was installed in a refractory wall furnace. As the refuse rose in LHV (the refuse became hotter), the refractory could no longer stand the higher temperatures. As a result, the currently standing plant was built with a combination of refractory and water tube walls.

Currently at Duesseldorf, there is a bulk waste shear ajoining the main refuse pit. There is also a Hazeman shredder in a separate building (See Figure G-2).

The single conveyor from the shredder drops its "hotter" dryer shredded waste into the pit between furnace lines No. 4 and No. 5. Lines No. 1 through No. 4 were the originally constructed furnaces. Unit No. 5 was designed later expecting this hotter waste and has had few problems. Unit No. 4, however,which was properly designed for a "cooler" waste now has problems with the hotter material.

Temperatures are higher, boiler corrosion rates are higher, ash fusion on boiler tubes is more prevelent and there is more high temperature corrosion in the electrostatic precipitator. Compared to what is needed, the original units do not have enough heat transfer surface area before the hot gases reach the superheater tubes.

After the problem was discovered it was hoped that the crane operator could evenly distribute the hotter shredded waste over all five furnaces. Unfortunately the two active cranes are so busy feeding the furnaces, that the material does not really get down to units No. 1 and No. 2. During Battelle's three visits in 1976 and 1977 the shredder was not in service. In future plant designs, consideration will have to be given to either (1) distributing shredded refuse evenly with the unshredded material or (2) designing the furnaces near the shredded material to accept a hotter load. One point is

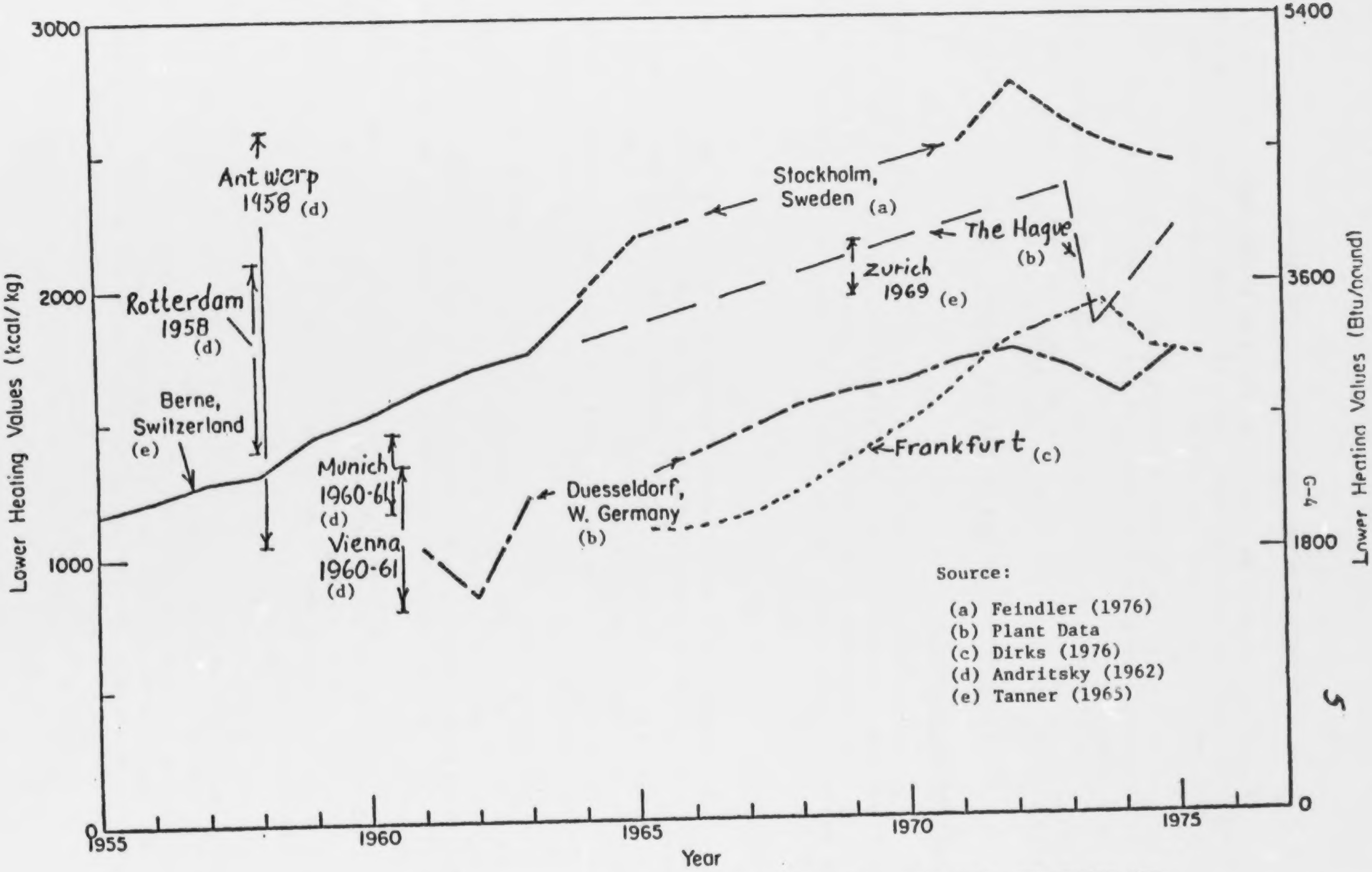


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FIGURE G-1. ANNUAL AVERAGE LOWER HEATING VALUES FOR BERNE, STOCKHOLM, FRANKFURT, THE HAGUE AND DUESSELDORF AND RANGE OF VALUES FOR OTHER CITIES (See References at end of chapter S - Furnace Wall)

TABLE G-2. REFUSE LOWER HEATING VALUES: ASSUMPTION FOR PLANT DESIGN AND ACTUAL

		Refuse Lower Heating Value (kcal/kg)					
		Assumed LHV for Plant Design			Actual LHV		
Trip		Low	Medium	High	Low	Medium	High
1	Werdenberg-Liechtenstein				2,800		3,360
2	Baden-Brugg				1,700	1,800	1,900
3	Duesseldorf					1,700	1,800
4	Wuppertal				900	2,250	2,600
5	Krefeld					1,750	
6	Paris:Issy	900		2,500	1,700		1,900
7	Hamburg:Stellinger-Moor	1,800	1,900	2,200	1,800		2,500
8	Zurich:Hagenholz						
	No. 1-3	1,000		1,800			
	No. 4	1,600		3,300	2,200		2,400
9	The Hague						
	No. 1-3		2,066				
	No. 4		2,500		1,800	2,100	2,300
10	Dieppe						
11	Goteborg				2,300		2,400
12	Uppsala						
13	Horsens	1,800	2,000	2,200	2,500	2,800	3,140
14	Copenhagen:Amager	1,000		2,500		2,200	
15	Copenhagen:West					2,200	
	AVERAGE	1,420	2,117	2,540	1,967	2,100	2,430

TABLE G-3. ENERGY VALUES OF SELECTED REFUSE COMPONENTS (DRY)

	kcal/kg
Average waste	1600 - 3400
Constituents (in relation to the dried products)	
paper	4160 - 4460
plastic, leather, rubber	5600 - 6450
food waste	4775
textiles	4500
wood	4820
Forest and wood industry residues	4090
Agriculture and food industry waste	2780
Tires	8230
Bituminous coal	5600 - 8100
Gasoline	11400
Methanol	5420

Source: Various sources.

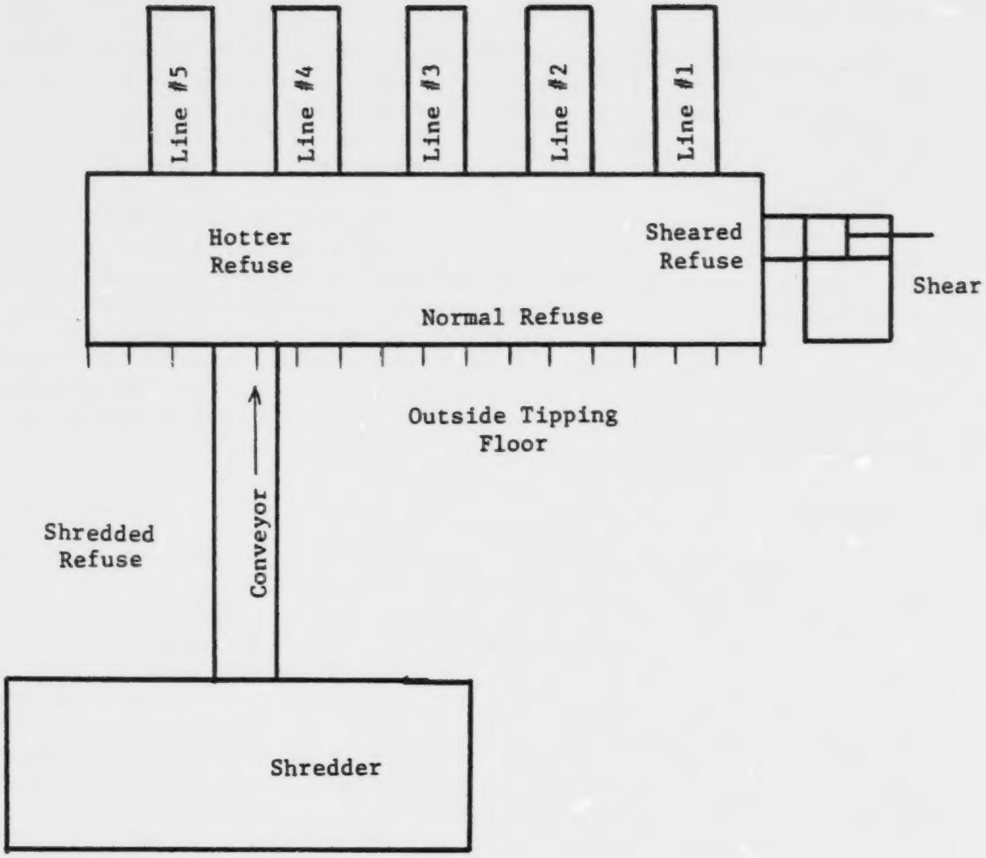
Line #5
Line #4
Line #3
Line #2
Line #1
Hotter Refuse
Sheared Refuse
Shear
Normal Refuse
Outside Tipping Floor
Shredded Refuse
Conveyor
Shredder

FIGURE G-2. SHREDDER AND SHEAR LAYOUT AT DUESSELDORF clear, excessive amounts of hotter shredded waste should not be casually mixed with normal waste unless a proper system is designed. Table G-4 shows that from 1961 to 1975 at the Duesseldorf plant, the average lower heat value of refuse increased 70 percent, 4,292 kJ/kg to 7,314 kJ/kg (1,025 kcal/kg to 1,747 kcal/kg)(1,845 Btu/lb to 3,145 Btu/lb).

Hamburg:Stellinger-Moor

The Hamburg:Stellinger-Moor plant was designed with an upper LHV bound of 2200 Kcal/kg which apparently seemed reasonable at the time. However, today's actual upper limit approaches 2,500 Kcal/kg. It appears that primarily for purposes of waste disposal (in contrast to energy purposes at Zurich) more industrial loads than anticipated have been received and combusted.

For example, on two separate occasions in three days, Battelle researchers observed full truck loads of Agfa film being dumped into the pit. This hotter waste has had a predictable effect on the Stellinger-Moor maintenance record. The record of precipitator maintenance due to hot flue gas is poor as described later in the Air Pollution Control section.

Here the recommendation is that the plants be very selective of the industrial waste that is allowed to be burned. For the purposes of protecting the refuse to energy plant, some of the local industries will have to find other disposal means for its hot waste.

Zurich:Hagenholz

A different motivation has resulted in similar maintenance problems at Zurich:Hagenholz. Actually the total situation is very complex and thus only one portion will be treated here. Back in the mid 1960's Units No. 1 and 2 were designed assuming 1,000 to 1,800 Kcal/kg. This was based on information available in the late 1950's and early 1960's. Again unfortunately with the increase of packaging, paper and industrial waste; the heating value has increased.

The motivation in Zurich is slightly different in that Hagenholz is primarily an "energy plant" and secondarily a "waste disposal plant". Hagenholz is one module of the city's district heating system.

Zurich officials (more than have been observed elsewhere) provide special incentives for industry to bring free and "hot" waste. Apparently the economics of having more than normal boiler down time on Units No. 1 and No. 2 are more than compensated by the savings in purchased fuel oil, etc. at the other conventional fossil fuel district heating plants in Zurich.

In the belief that a "refuse energy" plant (as contrasted with a "refuse disposal" plant) could be built, the local director Max Baltsenberger, worked every Friday with a Joseph Martin project engineer to design Unit No. 3, a suburb plant. The trip report on Zurich lists over 35 design features that have produced amazing results. At the time of Battelle's visit, this plant had been consuming high calorific waste for 30,000 hours. The superheater tubes had only 0.3 mm (0.012 in) corrosion and the furnace water wall tubes had lost only 0.1 to 0.2 mm. (0.004 to 0.008 in).

TABLE G-4. HEATING VALUES FOR MIXED MUNICIPAL REFUSE IN REFUSE POWER PLANTS (Courtesy of Klaus S. Feindler)(1)(5)

	Duesseldorf(2)			Stockholm(3)
Year	Minimum Btu/lb. (kcal/kg)	Average Btu/lb. (kcal/kg)	Maximum Btu/lb. (kcal/kg)	Average Btu/lb. (kcal/kg)
1961	--	1,845 (1,025)	--	--
1962	--	1,530 (850)	--	--
1963	--	2,196 (1,220)	--	--
1964	--	--	--	3,546 (1,970)
1965	--	--	--	3,942 (2,190)
1966	--	2,468 (1,371)	--	4,050 (2,250)
1967	--	2,621 (1,456)	--	--
1968	--	2,792 (1,551)	--	--
1969	--	2,882 (1,601)	--	--
1970	--	2,948 (1,638)	--	--
1971	--	3,087 (1,715)	--	4,545 (2,525)
1972	2,911 (1,617)	3,164 (1,758)	3,299 (1,832)	4,950 (2,750)
1973	2,803 (1,557)	3,037 (1,687)	3,242 (1,801)	4,680 (2,600)
1974	2,666 (1,481)	2,855 (1,586)	3,203 (1,779)	4,500 (2,500)
1975	2,954 (1,641)	3,145 (1,747)	3,374 (1,874)	4,410 (2,450)

(1) Annual Averages of the Lower or Net Heating Value LHV in Btu/lb.

(2) Source: Operator of MVA Duesseldorf.

(3) Source: Vereinigte Kesselwerke A.G., Duesseldorf.

(4) Stockholm refuse reportedly contains a fairly high percentage of plastics.

(5) To convert from kcal/kg to KJ/kg multiply by 4.1868.

Copenhagen: Amager and West

As calorific values have increased, manufacturers of refractory wall units have been faced with design challenges so that the refractory walls do not crack, spall or explode. At the two Copenhagen plants, Amager and West, Volund installed flue gas recirculation systems. A percentage of oxygen poor flue gas exiting from the electrostatic precipitator is recycled back to the secondary air system. While it has a temperature of about 300 C i.e. hotter than ambient air, it cools the furnace because it dilutes the hoter furnace gas with oxygen poor gas. A furnace thermocouple can automatically control the amount of flue gas recirculated.

REFUSE GENERATION AND BURNING RATES PER PERSON

Refuse generation rates are not always equivalent to refuse burning rates. There occassionally is the tendency to confuse the these rates for several reasons. Sometimes people will report a generation rate that includes construction waste, demolition debris, power plant ash, sewage sludge, waste oils and solvents, pathological waste, etc. The above items are normally not permitted into the refuse pit and are hence excluded from any calculation of the per capita refuse burning rate. Household bulky waste is sometimes accepted into the pit depending on the particular system.

Readers of this report are presumably interested primarily in "solid combustible waste loads" that are "combusted to produce energy". Thus Table H-1 was constructed to show reported tonnages of only combustible loads of refuse (household, commercial and light industrial) that are combusted at the visited refuse fired energy facility. The figures have been divided by the generation population as accurately as is possible.

The following (Table H-2) shows a range of Battelle estimates of the burning rates per person. The figures are shown per year and per operating day. Tracing through the background assumptions, we believe that an average or best estimate for household refuse plus some light commercial waste is 318 kg per person per year. The range from this estimate varies by country, by population density and by availability of alternative disposal means.

However, the range on burning other commercial and light industrial is waste is more dramatic. The amount of light industrial waste varies extensively depending on (1) local industrial composition,(2) whether the facility has a shear, (3) opening of the feed chute and (4) policy of the operator. In this waste category, the rate can vary from 25 to 100 kg per person per year. It is really more meaningful to emphasize the range than to concentrate on an average. But if one assumes a 45 kg per person per year average, the total household, commercial and light industrial waste generation rate becomes:

- 363 kg per person per year (or)
- 800 pounds per person per year (or)
- .99 kg per person per day (or)
- 2.19 pounds per person per day

TABLE H-1. QUOTED* REFUSE BURNING RATE ON A 7-DAY BASIS (DOES NOT INCLUDE ALTERNATE DISPOSAL MEANS)

		Refuse Burning Rate					
		kg/person/year			kg/person/day		
Trip		Low	Average	High	Low	Average	High
1	Werdenberg-Liechtenstein		342			.973	
2	Baden-Brugg	285	297(a)	305	.781	.814	.837
3	Duesseldorf		355			.973	
4	Wuppertal						
5	Krefeld						
6	Paris:Issy						
7	Hamburg:Stellinger-Moor		293			.803	
8	Zurich:Hagenholz		310(b)			.849	
9	The Hague						
10	Dieppe (and Deauville)						
11	Gothenburg		380			1.041	
12	Uppsala		342			.937	
13	Horsens		295			.808	
14	Copenhagen:Amager		451(c)		.8	1.100	1.500
15	Copenhagen:West		445			1.219	

(a) National average of 42 Swiss refuse burners.

(b) Includes 351 kg/person/day of household refuse and 1,000 kg/person/day of commercial and light industrial refuse.

(c) the 1976 Baden-Brugg estimate includes 267 kg/person/year of household and light commercial refuse. Another 30 kg/person/year is added for other commercial and light industrial refuse. This brings the total to 297 kg/person/year.

* To connect from a yearly figure to a daily figure divide by 365 days per year even though some systems operate only 5, 5-1/2 or 6 days per week.

TABLE H-2. EUROPEAN AVERAGE REFUSE GENERATION AND BURNING RATES PER PERSON (1976-1977 PERIOD)

	Household and Light Commercial	Other Commercial and Light Industrial	Total Combustible Loads[b]
		kg/person/year	
Low	275	25	300
Average	318	45	363
High	350	100	450
		pounds/person/year	
Low	605	55	660
Average	700	100	800
High	770	220	990
		kg/person/day	
Low	0.75	0.07	0.82
Average	0.81	0.12	0.99
High	0.96	0.27	1.23
		pounds/person/day[a]	
Low	1.66	0.15	1.80
Average	1.92	0.27	2.19
High	2.11	0.60	2.71

(a) Calculated at 365 days/year even though some systems operate only 5, 5-1/2, or 6 days per week.

(b) Full weight of contents in a vehicle where contents are destined for combustion.

Source: Battelle estimates.

DEVELOPMENT OF THE REFUSE FIRED ENERGY GENERATION TECHNOLOGY AND DEVELOPMENT OF VISITED SYSTEMS

This section is divided into three major parts as follows:

- Development of the Refuse Fired Energy Technology (1896 to 1982)
- General Comments about Development of Visited Systems
- Specific Comments about Development of Visited Systems

DEVELOPMENT OF THE REFUSE FIRED ENERGY GENERATOR TECHNOLOGY (1896 to 1982)

Producing and utilizing energy from refuse combustion goes back many years. One early account described in 1896 a small refuse-to-electricity and industrial steam plant in Hamburg, Germany located on Rohrstrasse. There were other turn of the century refuse to energy plants located at Paris and Zurich.

But the Europeans were not the only ones active in this field. There was the Delancey street plant in New York City, that produced electricity to light the Williamsburg Bridge in 1906. There was yet another plant on Staten Island about the same time. Based on knowledge of five systems prior to 1910, we might predict existence of two or three times that many small plants in those early days.

The above points out one fact. The first systems were sophisticated enough to produce electricity. They were not just simple hot air generators. The early units were refractory walled and thus the quality (temperature and pressure) of the steam was limited and efficiency was very low. There were many advances in design evolved by the various vendors.

During the period from 1910 through 1945, there were many improvements to the overall systems and to the art of boiler making. Also, during this time there was increasing concern aobut the wastefullness of using valuable land for unsightly landfills. There was also rising concern about effects on ground water contamination.

Then in the late 1940's and 1950's, vendors primarily Von Roll began to develop ways to take more energy out of the combustion gases. This effort was spearheaded by Mr. Richard Tanner who has since retired from Von Roll. Many consider him the primcipal originator of the modern-day water-tube wall refuse combuster. Basically he applied to refuse combustion what others had been learning about coal combustion in water-tube wall units.

As explained in the Boiler Section, the "water-tube wall furnace/boiler" has the refuse combustion section surrounded by steel tubes in parallel, usually sloping or vertical. In this way about half of the energy in the flame is absorbed before the gases enter the regular boiler convection section. This increases heat absorption efficiency and the tubular construction allows a much higher pressure steam to be produced.

By 1965 the people in Europe and Japan, in contrast to the United States, were fearing more and more the long term landfill effects. These fears were strong enough to cause many cities to choose refuse burning. They were, and still are, willing to pay a premium price for refuse burning over landfilling. In many cases the refuse burning option would be two, three or four times as expensive as landfilling.

The Japanese, since 1965, have become increasingly conscious of what is put into close-in fishing waters off the Japanese coast. Their diet is so heavily tied to saltwater fish. Analytical tests for heavy metals ahd harmful organics showed dangerous concentrations. Industry, municipal sewage plants and landfills were blamed for these concentrations.

In addition to landfills on normal land, the Japanese have long reclaimed the sea with trash. In fact, this author spent an afternoon in 1975 on the 180 acre "Dream Island" in the Tokyo Bay. Pilings had been driven. Household refuse and construction debris were then dumped in. Now after many years, the waste has settled and several buildings have been constructed: including the attractive 1800 ton per day Koto Incinerator built by Takuma. However, sea filling of household refuse is no longer permitted in the sea. Instead Japan has become the world's most active builder of refuse fired steam generators--primarily due to their fear of landfill or seafill leachate effects.

Prompted by the dangers of leachate and concern for scarcity of land, many European countries and cities had refuse burning construction programs from 1960 to 1973. Acutally by the time that the Arab Oil Embargo occurred in 1973, some countries were saturated with plants. The effect of doubling or quadrupling of energy prices was not all that noticeable on new orders. These authors have concluded that energy considerations have never been and are not now the driving force leading to construction of energy systems.

Cities build refuse fired energy systems because they fear the long term effects of landfill leachate, and they preceive a shortage of land. OPEC oil prices would have to rise dramatically before the basic motivation for resource recovery changes from matters of landfilling to energy matters.

The next force on the development was the pressure to clean up the atmosphere. It is hard to know exactly when this pressure began building, but it was well noticed during the 1960's. Air pollution control had a substantial effect on energy production and utilization. Air pollution control equipment was needed after the combustion and before the stack. Then and now, all such air cleaning equipment would deteriorate until ineffective with excessively hot flue gas passing through them. Thus the combustion flue gases had to be cooled.

Three methods exist: (1) the water spray cooling tower, (2) massive air dilution and, (3) the boiler. There were communities with refuse but not a sufficiently concentrated energy demand to make energy production realistic. Hence many systems were built with only a cooling tower before the (1) baghouse, (2) scrubber or, (3) electrostatic precipitator. Unfortunately, the moisture inherent in such water spray systems would remain in the ductwork and the air cleaning device when the unit was shut down. This caused excessive "dew point" corrosion.

To prolong the life of the air cleaning equipment, boilers were installed whenever there was a desirable market for energy.

General Comments About Development of Visited Systems

Motivations and Decision Making

One of the motivations for commissioning this study was to determine answers to several basic questions as follows:

1. Why, in 1977, were there about 275 refuse fired energy systems in Europe and less than 20 in the United States.
2. Are the conditions prior to 1977 in Europe and the U.S. still in existence?
3. Is the situation in the U.S. such that the ratio should continue or should U.S. communities begin developing their systems?

By examining why Europeans decided on their own local systems, we have endeavored to determine motivation and decision making patterns. Going into the project, these authors had about a dozen hypotheses for the difference between the two continents. Some have been verified while others have been discarded. New motivations have been added.

Main Purpose - Waste Disposal? or Energy Production?

In general we can conclude that the "primary motivation" for constructing European refuse to energy plants has been to replace an existing landfill, compost plant or incinerator or to add additional solid waste disposal capacity. At none of the 15 major or 15 minor visits was the primary motivation connected with energy production.

However (and this is the confusing concept to many), some of the best systems are operated with the "primary objective" of energy production. Stated another way, the strategic overall goal is to destroy refuse: while the tactical detailed goal is to provide energy of reliable quantity and quality to offset disposal costs. Perhaps the lesson to be learned is:

- Let the elected officials and community leaders decide to build and finance the refuse burning plant.
- Let the engineers, planners and economists design and let the staff operate the energy plant for minimum cost to taxpayers.

Occasionally at a resource recovery conference, a debate is held leading to an "either-or" conclusion. Often after a series of speakers have discussed the technical aspects of their plant, an agitated local official will rise from the floor to explain, "I don't really care about the energy. I've got 500 tons per day of garbage to get rid of. Can I burn it?"

The fact is that concentration on energy matters is necessary. Otherwise the expenses of refuse burning, gas cooling and air pollution control could not be paid for. Energy sales are necessary to lower the net disposal or tipping fee. To sell energy, it must be produced reliably.

In the following are reasons that should explain developments of visited systems.

Stated Reasons for Development of Refuse Fired Energy Systems

Table I-1 shows the stated reasons "phases" associated with each unit. Frankly as the interviews matured from the early ones in Switzerland to the later ones in Scandanavia, the level of detail increased. The reader will therefore notice an increase in the number of reasons per plant---that only relfects interviewing technique.

The results have been retabulated in Table I-2 show the rank order of mentions out of a 15 possible total. The results are rearranged again in Table I-3 by reason and by plant.

Component of Energy and Environmental Park. The biggest surprise of the trip was the overwhelming presence, 14 mentions, of energy and environmental parks. These parks are a recurrent theme of this report. Only at Wuppertal, does the facility stand by itself. At the other

TABLE I-1. PHRASES ASSOCIATED WITH DEVELOPMENT OF VISITED SYSTEMS

Werdenberg-Liechtenstein

disappointment with composting
growth in waste collected (historical fact)
federal government grant program

Baden-Brugg

growth in waste collected (future estimate based on population)
unexpected increase in population
federal government matching fund grant program

Duesseldorf

landfill volume reduction
growing problems of solid waste disposal
enthusiasm from local city engineers to develop new systems

Wuppertal

landfill life estimated to be only 10 years
composting considered but too much inorganic waste
incineration would triple life of existing landfill to 30 years

Krefeld

city landfill was past half of its useful life
compost was tried on small pilot scale to extend landfill life
landfill became such a steep pile that operations became dangerous
frequent refuse fires caused annoyance from smoke and odors
composting was not promising
study showed "that incineration would be the best of the alternatives" but "it is also the most expensive alternative"
optimim solution to place refuse incineration plant next to waste water treatment plant
searched for another alternative-rail haul
geology of distant landfill unfavorable for proper land disposal
re-estimate landfill life to expire in 5 or 10 years
returned again to co-disposal

Paris:Issy

historical pattern since 1903 incinerator
first incinerator with heat recovery in 1928
period of composting and landfilling 1955 to 1965
citizens voted to build third plant in 1960

TABLE I-1. (Continued)

Hamburg:Stellinger-Moor (S-M)

the first refuse to electricity in Europe 1896
continuous waste energy pattern since
second unit in 1930
third unit in 1952
fourth unit in 1962
S-M conceptuatized in 1930 for construction when NW suburb population grows
purchased land decades ahead for sanitary park
fifth unit S-M in 1970-72
sixth unit in 1971 for industrial waste
seventh unit in 1977 during visit in NE suburb
Hamburg is the world's first city to commercialize refuse to energy---in 1896. It has continued unwavering in its commitment to mass burning of municipal refuse to produce useful energy---81 years of devotion to this single concept

Zurich:Hagenholz

historical pattern of waste-to-energy since 1904--74 years
overloading and corrosion
short period of landfilling on farm land
old district heating system
long range plan called for two facilities
emphasis on energy production
surprise at rising calorific values
emphasis on technical reliability rather than cost

The Hague

first incinerator (without energy recovery) in 1919
many citizens favored land recovery from sea
lower incinerator operating rate and began landfilling in sea
railed refuse to distant inland compost plant for 30 years
compost used as soil conditioner for "polder" recovery in the Zider Zee
cost of rail haul increased
study, principal objection of solution "to meet high hygienic standards inherent in other solutions'
fuel prices were high - 1964
possibility to recover heat energy from refuse promised attractive revenues

Dieppe (Brive and Deauville)

used uncontrolled landfills prior to 1971
smokey fires at the landfill
growing scarcity of available landfill area

TABLE I-1. (Continued)

Dieppe (Continued)

composting rejected because of lack of assured market for product
district heating rejected because of only two factories and poor summer load in addition to the poor winter load
electricity production rejected because electric utility would not guarantee revenue
local officials became aware of unique sludge drying process
need for sludge disposal method

Gothenburg

seven small refuse fired hot water generators prior to 1971
used in connected district heating system
remainder of waste to uncontrolled landfills
air pollution from old incinerators was a problem
had considered large landscaped hills--"Mt. Trashmore" as at Stockholm and several U.S. cities
discuss better ways of doing it
concensus of central facility would be more desirable
siting was originally difficult

Uppsala

compost plant in 1950's
market for compost material could not be maintained
pressure in 1960 to find another disposal method
large and integrated environmental improvement and energy conservation program started by City Council in 1960
program: district heating, electrical production, refuse-energy oil fired boilers to begin
in summer refuse is base load, oil is standby
some suburb areas have portable oil-fired boilers
1970 decision for pulverizer for industrial waste

Horsens

uncontrolled landfill
landfill fires and rats
City Council determined it had to be replaced
environmentally more acceptable method
unsatisfactory experience with modern composting: 1951 to 1965
from the start, assured markets for compost would not be maintained
in last five years of operation none (compost) was sold
visited 10 cities who had chosen refuse to energy systems

TABLE I-1 . (Continued)

Horsens (Continued)

- well managed landfills cost 1/2 to 1/3 as much to operate as incinerators
- but acceptable sites for new landfills are rare
- desire to utilize heat
- plan included new sewage treatment plant
- important incentive toward clean alternatives to landfilling is the threat to groundwater quality from old uncontrolled landfills
- since Denmark imports all of its energy, the recovery of energy from wastes has long been an important goal
- oil crisis of 1973 intensified the need for more waste to energy systems
- additional refuse fired steam generators are envisioned
- national legislation will likely require greater use of district heating

Copenhagen (Amager and West)

- waste to electricity since 1930's - 2 facilities
- 40 year experience at each plant
- "Knowledge" of landfill leachate damages became better known
- neighbors became upset over blowing trash
- local citizens got attention of elected officials
- originally, each community wanted to solve problem alone finally one community decided on resource recovery, others followed
- eventually got attention of metropolitan government
- study by regional utility
- recommended two units: Amager and West
- quantity discount for both units

TABLE I-2. RANK ORDER LISTING OF REASONS MENTIONED FOR DECIDING TO CONSTRUCT A REFUSE TO STEAM OR HOT WATER PLANT

Component of Energy & Environmental Park	14
Long Term Policy Against Leachate from Landfills	8
Compost Plant Closed	6
Long History of Incineration (Replace Old Incinerator)	6
Need for Electricity	6
Landfill About to Expire	5
Need for District Heating	5
Country Imports Most of Energy	5
National Policy Favoring District Heating Systems	5
Fires, Odors, Rats, Blowing Refuse at the Landfill	4
Included in Very Long Range Plans	4

TABLE I-3. MATRIX OF STATED REASONS FOR DEVELOPMENT OF REFUSE FIRED ENERGY SYSTEMS

	WERDENBERG-LIECHTENSTEIN	BADEN-BRUGG	DUESSELDORF	WUPPERTAL	KREFELD	PARIS:ISSY	HAMBURG: STELLINGER-MOOR	ZURICH: HAGENHOLZ	THE HAGUE	DIEPPE	GOTHENBURG	UPPSALA	HORSENS	COPENHAGEN: AMAGER	COPENHAGEN: WEST	TOTALS
I. LANDFILL																
A. About to Expire	X	X	X	X	X											5
B. No New Sites										X			X			2
C. Fear of Leachate										X			X	X		3
D. Fires, Odors, Rats, Blowing Refuse					X					X			X	X		4
E. Dangerous Operation					X											1
F. Recovery of Sea Expensive									X							1
G. Rail Haul																
(1) Closed									X							1
(2) Never Opened					X											1
II. COMPOST																
A. Closed-Not Able to Market Compost	X				X	X			X			X	X			6
B. Never Started																
(1) Fear of Failure to market					X					X						2
(2) Too Many Inorganics				X												1
III. INCINERATION																
A. Old Incinerators Had Air Pollution											X					1
B. Long History of Incineration						X	X	X			X			X	X	6
C. Would Extend Life of Existing Landfill - Ash Only			X													1
D. Incineration Is Hygienic					X				X							2
E. Excitement to Develop New System			X													1
F. Need More Capacity						X	X	X								3
IV. NEED FOR ENERGY																
A. Higher Fuel Prices									X				X			2
B. For District Heating						X	X				X	X			X	5
C. For Electricity			X	X		X			X		X	X				6
D. For Sludge Drying					X					X			X			3
E. Country Imports Most of Energy											X	X	X	X	X	5
F. Component of Energy and Environmental Park	X	X	X		X	X	X	X	X	X	X	X	X	X	X	14
V. FEDERAL INCENTIVE																
A. Federal Matching Grant Program	X	X														2
B. Long Term Policy Against Leachate	X	X							X		X	X	X	X	X	8
C. Policy Favoring District Heating											X	X	X	X	X	5
VI. MISCELLANEOUS																
A. Very Long Range Plan (20+ years)						X	X	X				X				4
B. Even Though Expensive	X				X								X			2

facilities, one will find various energy and environmental modules. The energy from refuse is needed to driie some of these other modules.

At other systems odiferous gases from rendering plants, pathological incinerators etc. are sent to the refuse burner as overfire air. The offending particles and gases are destroyed by combustion.

Long-Term Policy Against Landfill Leachate. A true difference in continental attitudes is associated with landfill leachate. In frequent conversations, the attitude was expressed, "We just can't have the percolate (leachate) entering our rivers, streams, groundwater, drinking water, etc.".

When pinned down for damage results, the effects are not clearly known. Studies have been conducted in Europe that confirm travel patternns of leachate. Many disease and cancer results are assumed. Similar studies and assumptions apply to America. Yet, we have observed more intense fear and opposition to landfill leachate in Europe than in North America.

One of the reasons for the average American not being as concerned with leachate is the sanitary landfill program inspired by the U.S. Public Health Service, U.S. Environmental Protection Agency and one leading earth moving equipment manufacturer. This developmental program evolved during the late 1960's and early 1970's. EPA has poured technical talent and promotional effort into the concept. The U.S. Environmental Agency's position was summarized in the excellent 1972 publication of Sanitary Landfill Design and Operation.*

> An acceptable alternative to the present poor practices of land disposal is the sanitary landfill. This alternative involves the planning and applying of sound engineering principles and construction techniques. Sanitary landfilling is an engineered method of disposing of solid wastes on land by spreading them in thin layers, compacting them to the smallest practical volume, and covering them with soil each working day in a manner that protects the environment. By definition, no burning of solid waste occurs at a sanitary landfill. A sanitary landfill is not only an acceptable and economic method of solid waste disposal, it is also an excellent way to make otherwise unsuitable or marginal land valuable.

Facing the agreed upon problem, leachate; the U.S. approach has been to "correct" the problem by operating a better landfill. Europe's approach has been to "avoid" the problem by burning the refuse and by recycling ash into useful products.

Failure of Composting. Solid waste treatment and disposal methods fall in and out of fashion over ten to twenty year periods. Shortly after W.W. II, many communities gegan compost operations using municipal solid waste as input. Some also used sewage sludge.

Six of the surveyed communities had compost operations that are now closed. None of the 15 major surveyed communities have composting operations anymore. All failed for the identical reason: A market for the compsot product could not be maintained.

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* Brunner, Dirk R., Keller, Daniel J. Sanitary Landfill Design and Operation. U.S. Environmental Protection Agency 1972

A most interesting brief visit was to Biel, Switzerland where the compost is used as a soil conditioner in vineyards. Only with such a uniquely favorable market could composting survive.

In Europe, many compost operations collapsed in the 1960's. Another disposal method was needed. Landfilling was feared. The communities with composting operations (40 percent in the survey) turned to refuse fired steam and hot water generators primarily for disposal. Perhaps 20 of 25 compost operations in the U.S. failed in a similar period for idential reasons.

Composting was never as prevalent in North America as it has been in Europe. When it failed in the U.S., the loss did not have a significant impact. Samitary landfilling was acceptable and the chosen option. Incineration was a "dirty" word in the U.S. due to its public association with air pollution.

Long History of Incineration. Forty percent (40 percent) of the communities surveyed have had long histories of refuse to energy as portrayed below:

City	Since
6 Duesseldorf	1960
2 Paris	1903
1 Hamburg	1896
3 Zurich	1904
5 Gothenburg	1952
4 Copenhagen	1932

The local organizations, staff, energy distribution method, etc., were well established before the plant visited was conceived. Momentum for refuse to energy was strong. To dismantle the preceding in favor of another alternative would likely cause a political and economic distruption perceived to be undesirable and unnecessary by locally elected officials.

Yet in the U.S. there have been several pre-W.W. II refuse to energy plants. However, none of the older units have been replaced in the U.S.

Landfill About to Expire (Hard to Locate new Acceptable Landfill). Five communities cited that they were about to run out of landfill capacity. Two different communities cited that there were no new sites to be found. Adding the two similar reasons provides a total of seven relating to "expiration of old" and "location of new" landfills. Apparently the only communities where this was not a key issue were where the new energy system would replace as older refuse to energy system.

Need for Energy. A need for energy "as supplied by refuse" was mentioned not because there is a critical shortage of energy but because energy sales help pay for accompanying expenses of refuse destruction.

In all systems, energy could be more economically produced using conventional fossil fuels. There are trend charts at Uppsala that portray hopes of refuse derived energy sales eventually being able to cover all plant and distribution expenses. Should this happen, the net disposal fee for the taxpayers would be reduced to zero. Only when the net disposal fee equals zero is the refuse derived energy as cheap as fossil fuel.

Respondents mentioned the need to energize their systems for electricity generation, district heating and sludge drying. Several noted concern for rising energy prices due to the Arab oil embargo, the eventual shortage of fossil fuels and the general need for energyconservation. Some countries have stronger national programs because nearly all of their energy is imported and there is a "need to be somewhat independent".

Economics. At no time did anyone give the impression that waste to energy was chosen because it was the lowest cost option. Frankly this was a surprise--that no community chose their refuse fired energy plant for economic reasons. Many, however, did choose the vendor based partly on his estimates of operating costs.

Actually the range of financial numbers in Europe is similar to the range of the few units in America. One of the smaller European plants visited briefly experiences a $48 net disposal fee (after sale of electricity). Yet another plant in a city with a long history of refuse to energy has a plant with a $6.27 net disposal fee.

Governmental Philosophy. In Europe, there is greater government involvement in both environmental and energy daily operations. Usually the community is responsible for waste collection, especially household refuse. The local government (municipal or authority) is always responsible for disposal. In all cases known to these authors, refuse fired energy systems are owned by he local government.

Many of these governments also assume responsibility for hazardous waste treatment and disposal. With the responsibility clearly defined, decisive action has been frequent by elected officials.

General Attitude. The general attitude can be characterized by the following statements:

- We don't like landfills
- We don't think that a compost product can reliably be sold
- American type front-end resource recovery seems to be needless because of the high processing cost, low materials revenues and that the energy plant doesn't need the uniform fuel
- So what's left?
- Refuse fired, mass burning, energy production.

Such logic leads to a sole consideration of the latter concept.

Unstated Reasons

Many attitudes and reasons were gleaned from the many formal interviews and social contacts during the trip that cannot be tied to any on system. These are attitudes or differences in political philosphy between the two contiuents. No quantification or ranking is possible.

Social Democratic Philosophy. Many countries visited are managed by elected officials voted into office by citizens that believe that government can do more for the citizens than private enterprise or individuals acting independently. Hence there has been a rise of coordinated municipal functions.

Not only is household refuse collected, processed and disposed but often hazardous waste is as well. We are not aware of any American municipality assuming such responsibility for hazardous wastes. In addition, local governments produce the electricity, distribute steam and hot water, operate animal rendering plants and dedicated industrial sludge incinerators.

The only way that this "responsible local government attitude" can progress is to accumulate enough tax revenue to purchase and operate these systems. In Europe as in America, resource recovery is normally more expensive than landfilling with prevailing practice at the time. An essential difference between the two continents is that European citizens are willing to subsidize resource recovery through increased taxes and disposal fees.

Capable and Eager Vendors. Europe has, perhaps by accident, been blessed with imaginative, progressive and aggressive grate/furance/boiler manufacturers that have skillfully developed the art of refuse fired steam generation. This has been the situation in America for many years with respect to grate/furnace designs for fossil fuels. It would appear that American boiler manufacturers have, because of the prevailing national attitudes, considered the refuse fired energy business as a step-child with their other main line markets for coal, oil and gas utility and industrial boilers. The U.S. has never supported enough of a market to encourage profit minded American manufacturers to invest enough resources to build up large competitive capabilities in refuse processing. The "chain-letter" building phenomena has not worked to effect a "build one-sell three or more, build three-sell nine more,..." progression. Indications are that several American grate and boiler companies may be beginning such experience chains.

Specific Comments About Development of Visited Systems

Werdenberg-Liechtenstein

As the waste disposal problem evolved in eastern Switzerland and Liechtenstein, three of the larger communities(Buchs, Switzerland; Vadus and Shann in Liechtenstein) began discussions of possible solutions. Some years ago composting plants were in vogue in Switzerland and one was built in Buchs. It cost about 1,000,000 S.Fr. and began operation in January, 1962. But gradually the plant became too small for the amount of waste being generated. Subsequently Incinerator I (without heat recovery) was built and started operation in Janauary, 1968. It cost about 2.5 million S.Fr. However, waste generation continued to increase at the rate of 20 percent per year and in mid-1969, it was decided that Incinerator I was too small. Accordingly, in 1970, the local Vereins fur Abfallbeseitigung (Society for Waste Management) invited proposals for a new incinerator, a waste-to-energy plant.

In December, 1971, the proposal of Widmer & Ernst was accepted and in January, 1972, construction began adjacent to the old incinerator and compost plants. The plant was built in about 28 months and operation began in April, 1974. It was dedicated on November 22, 1974, and provisional acceptance was made in July, 1975. Operation continued after the dedication while adjustments were made to firing rate and to component operation.

Baden-Brugg

In 1956, the separate communities of Baden and Brugg (16 km or 10 miles apart) began a study of alternate methods for solving their growing solid waste problems. This study envisioned by 1985 a population of 77,000 and a solid waste production of 20,000 tonnes (22,000 tons) per year. A common waste processing plant was recommended for the two communities. A compost plant midway at Turgi was recommended as a first step to be followed by an incinerator when needed.

In 1959, the Zweckverband Kericht-Verwertung Region Baden-Brugg (Baden-Brugg Waste Management Association) was formed and included eight other adjacent communities shown in previous figure. The compost plant construction was begun in April, 1960, and began operation in June, 1961. However, this plant could not handle bulky and industrial waste. In 1964, it became apparent that the amount of waste was increasing and the population served was then up to 120,000. Preliminary plans envisioned an incinerator using two furnaces. Each would handle 100 tonnes (110 tons) per day based on refuse having a lower heating value of 2,500 Kcal/kg (4,680 Btu/lb) (10,467 kJ/kg). The local firm of Motor-Columbus AG was engaged to study the feasibility of the plant which was to include heat recovery by steam and power generation. The best available exhaust gas cleaning method was to be used. In the spring of 1967, a furnace-boiler plant contract was agreed to with Alberti-Fonsar of Milan. At the end of 1967, a contract for the steam turbogenerator was given to the Baden firm of Brown-Boveri Company. Excavations were begun in February, 1968 and acceptance tests followed in February, 1970. The Association gave provisional acceptance in June, 1970 and steady operation began on November 10, 1970.

During the course of the development of the plant, some opposition was voiced in the local press, partly because of expectations of air quality impacts on the hills across the river. The stack height was specified in the original RFP.

There were five bids, all very similar in price.

Duesseldorf

Organized waste management by the City of Duesseldorf began in 1862. As early as 1897, the growing problems with solid waste disposal led to some consideration of incineration. However, not until 1957-1958 did an active search begin for some "new way" to process solid wastes. In

1960, it was decided to develop an experimental refuse-burning, heat-recovery type of furnace in the existing coal-fired Flingern municipal power plant near the center of the city.

It was at this retrofitted plant that the City of Duesseldorf engineering staff obtained the original patents for the "Duesseldorf", "rotary drum", "walzenrost", or "roller" grates, as they are alternately referred to.

Having learned sufficient information, this City Electricity system negotiated with VKW in Duesseldorf for VKW to make the Duesseldorf grates for the new totally refuse-fired plant built across the railroad tracks 2,700 feet away.

Wuppertal

The two industrial communities of Wuppertal and Remscheid began discussion in 1969 and 1970 on the possibilities for a combined facility for disposal of their solid wastes. At first, the deep valley adjacent to the present plant site was considered for landfill because it contained a water-filled quarry (later abandoned in 1973). However, the life of that landfill was estimated to be only 10 years. Composting had been briefly considered but because of the proportion of inorganic industrial waste expected, this alternative was not pursued.

Then the use of an incinerator was considered which would increase the life of the landfill to about 30 years for the residue only. This method was then agreed on and bids were invited. The VKW walzenrost (roller grate) system was selected because other examples in Germany showed effective burnout, low maintenance rates, and high availability. Construction began in October, 1971. Because of the well established technology for flue-dust removal from combustion gases which have been partially cooled by heat-recovery boilers, this technique was adopted.

In April, 1972, construction was halted because of the new Federal requirement that flue-gas scrubbers should be incorporated to control the emissions of chlorides and fluorides.* Compliance agreements were made and construction resumed 10 months later. The plant was completed in September, 1975. Operation began in January, 1976.

There was some minor local objection to the siting of the plant near the top of a deep valley adjacent to a community swimming pool. However, this did not affect plant plans.

Krefeld

In the 1950's, it became evident that the city landfill at Fluennertzdykt, operating since 1928, was past half of its useful life. An effort was made to develop a compost system. In the dedicatory brochure for the present Krefeld plant, dated March 11, 1975, Krefeld City Director Theo Fabel described the small pilot compost operation as built on the theory that a natural use of the waste would be better than burning. Meanwhile the Fluennertzdykt landfill became such a steep pile that operations on it became hazardous. Also, frequent refuse fires there caused annoyance from smoke and odors.

The composting effort was not deemed promising and in 1961, a Dr. Straub was engaged to study the alternatives. His report in 1964 suggested that incineration would be the best of the alternatives. Furthermore, the optimum solution suggested was to place an incineration plant adjacent to a wastewater treatment plant. However, although incineration was thought to be best, it is also the most expensive alternative. Thus, in view of the city's other needs for a bathing center, clinic, school, and new streets, there was a suggestion that rail haul be used to carry the refuse to abandoned clay pits at Lobberich. However, the geology of that facility was decided to be unfavorable for proper land disposal. Accordingly, an incineration plant had to be considered, especially since the Fluennertzdykt landfill was reestimated to be exhausted by 1975.

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* The plant was being retrofitted with scrubbers during the Battelle visit in May, 1977.

In 1970-1971, a feasibility study of a proposed plant was made considering the combined firing of refuse and dried sludge. The study was by Projekta of Duesseldorf for the City of Krefeld. On the basis of the feasibility report, Projekta then prepared the specifications for the plant. Four bids were received.

There were two methods for sludge burning considered. One, proposed by Vereinigte Kesselwerke, would partially dry the sludge in a centrifuge and then complete the drying in suspension in a hammer mill supplied with hot flue gases. The dried dust would then be conveyed by the hot gas flowing into the refuse-burning furnace.

The other method, proposed by Techfina (a part of Von Roll), would dewater it in a filter press, thermally condition the sludge, then fire it with the refuse on the grate.

On evaluation of the bids, the suspension burning system for the sludge was found to have a lower capital cost by DM 7.6×10^6 (\$$3.2 \times 10^6$). Also, the suspension burning method had already been developed for the drying and burning of high-moisture coals. Hence, it was judged to be ready for translation to sludge burning. In addition, mass burning of dried sludge along with refuse required about twice as long to burn sludge on a grate as does refuse. For these various reasons, the VKW bid was accepted. Construction of the plant began on May 18, 1973. Construction was essentially complete in late 1976 but acceptance tests were not expected at the time of our visit, May 20-23, 1977, until July, 1977.

Paris:Issy

Paris is a large, old, urban, metropolitan center. The structure of the community with respect to solid waste collection and disposal was established decades ago.

The first Issy incineration facility was built in 1903. The plant had three refractory lined batch ovens with no heat recovery capability. A second plant was built on adjoining land in 1928. This plant consumed about 130,000 tons/year in six continuous feed furnaces. This plant recovered energy with its three 6-Mw turbines producing a total of 18 Mw.

In 1946, EDF-TIRU assumed operational responsibility for the plant.

This second Issy plant was closed in 1955 and demolished in 1962. From 1955 through 1965, much of the southwest Paris area's waste was composted and landfilled.

In 1960, Parisians voted to build their third Issy plant. TIRU organized the bidding. They called for integrated bids on the "chute-to-ID fan". Other bids were solicited separately for civil engineering, feedwater systems, turbines, components, chimneys, ash recovery, landscaping, etc.

When asked why Martin was chosen, officials made the following reply:

(1) Local officials were most impressed by the Martin grate as seen in Sao Paulo, Brazil. (However, Sao Paulo heats only combustion air, not steam.)

(2) Martin suggested to use the new Issy plant for experimentation both by Martin engineers and by TIRU staff. (This arrangement has facilitated the development of the TIRU staff into one of the best local operating organizations in Europe.)

(3) In the point system evaluation procedure, Martin was granted 10 points over competition for its thermal efficiency. Martin had previous experience in coal plants.

(4) Integration of a grate and boiler system was not new to Martin. At that time, the concept was fairly new to some of the other competitors. TIRU wanted an "integrated" refuse-fired steam generator as contrasted with a refractory wall furance and grate followed by a waste heat boiler.

(5) In 1962, the biggest unit in France was the 8-ton/hour facility at St. Ouen (Volund's grate followed by a rotary kiln). TIRU, however, wanted a very large unit. Martin, with its modular three multiple runs could offer a 15-ton/hour system. With limited land available for more units and with TIRU's desire for efficienly produced electricity, they opted for Martin.

The above was cause for Martin to be chosen despite Martin's "chute-to-ID fan" price being 50 percent higher than some of the competition.

There were few notable events or interruptions associated with the construction.

Hamburg:Stellinger-Moor

Hamburg has been involved with refuse to hot water and steam concepts since 1896. This first European experience in converting refuse to electricity was with 12 batch-fired incinerators with waste heat recovery boilers at Rohrstrasse. Later in 1930, six parallel Lurgi furnaces with waste heat recovery boilers began consuming refuse in the Borgigstrasse area.

The third major procurement was in 1952 when four 8-ton/hour Von Roll furnaces were added. In 1962, three more 8.33-tonne/hour Von Roll furnaces were added. These furnaces were designed for 1,500 Kcal/kg (2,700 Btu/pound) but now combust higher quality refuse at 1,900 Kcal/kg (3,420 Btu/pound).

The Stellinger-Moor plant was conceptualized around 1930 when long-range plans were formulated. Basically, community leaders agreed that such a system should be built when the population increased enough in the northwest suburbs.

Fortunately in 1965, when the question was raised again, the city had long since purchased much land for a sanitary park. Serious discussions began with many firms in 1968. Many vendors were asked to express interest. These five firms responded:

- Martin
- Von Roll
- Claudius Peters
- VKW*
- Durr*.

The city engineering staff prepared the "Call for Tender". The above five companies submitted proposals.

Dr. Reimers of the Hamburg consulting firm, Geopfert & Reimers, evaluated the five proposals. Martin was chosen.

Since the subject plant was built, two other developments have occurred. In 1971, a private firm built Abfall Verbrennungs Geselschaft. This plant consumes industrial refuse (pallets, cardboard, oil, sludges, etc.) in two Wiedemann rotary kilns. An explosion in 1977 shut the facility down for 2 months. As a result, again oil was mixed with household refuse in the Stellinger-Moor bunker.

The final development is the Staplefeld plant being built by a consortium of local people and Widmer & Ernst with the Steinmueller grate.

City engineers emphasized, "We have tried Lurgi, Von Roll, Martin, and Widmer & Ernst (Steinmueller). We are not married to anyone. We'll try them all".

The construction at Stellinger-Moor, begun in 1970, was completed in 1972 35 months later. There were no major problems. A few minor problems delayed construction for a half year.

Zurich:Hagenholz

Background. Zurich began its long history of converting waste into energy back in 1904 at the unit pictured in Figure I-1 on Josefstrasse. In fact, efforts are now proceeding to develop a 75-year anniversary brochure that will be released in 1979.

Operations continued until 1927 when the plant was temporarily closed for rebuilding. The plant reopened in 1928. Refuse consumption rose from 30,000 tonnes (33,000 tons) per year to 70,000 tonnes (77,000 tons) per year in 1959. Between 1959 and 1968, the overloading results became pronounced as corrosion repairs increased. During the period, extra waste had to be landfilled on farmland. By 1969, tonnage consumption had dropped to 50,000 tonnes (55,000 tons).

By 1965, a long-range plan had been developed where two large refuse-fired steam generators (RFSG) units would be built--one on each side of the Limmat River (the river flowing through the old city's centrum). Because Josefstrasse was south of the river, officials decided to build a 520-tonne (572-ton) per day facility at Hagenholz, a northern suburb. This was one of the few remaining open industrial spaces in the city.

Partially because of Von Roll's local presence and because of their excellent reputation throughout Europe, Von Roll was chosen to build two 260-tonne (286-ton) per day units with room set aside for a third unit later on. The construction begun in 1966 was completed in 1969. Waste

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* Both VKW and Durr are now part of Deutsch Babcock operations.

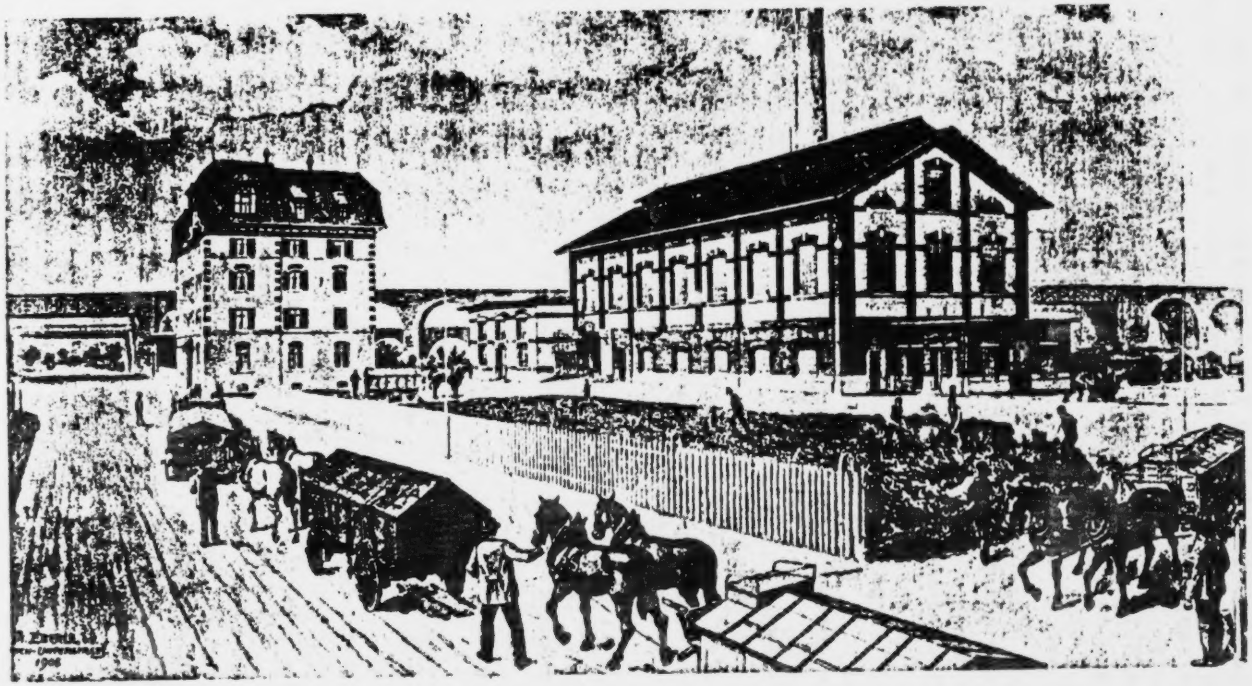

FIGURE I-1. ARTIST SKETCH OF THE 1904 REFUSE FIRED STEAM AND ELECTRICITY GENERATOR AS MANUFACTURED BY HORSFALL-DESTRUCTOR CO. AT ITS LOCATION ON JOSEFSTRASSE IN ZURICH.

consumption immediately jumped to about 170,000 tonnes (187,000 tons) per year at both plants.

At Hagenholz, most parties back in the early 1960's underestimated the heating value in 1965 and grossly underestimated the value for the 1970's. As a result, the system (1) was grossly overheated, (2) had been designed with low furnace wall tube surface area for heat removal prior to the superheater, (3) had small boiler passes designed, (4) suffered with slagging on furnace walls and tubes, (5) developed corrosion on boiler tubes, (6) developed high temperature corrosion in the lectrostatic precipitator, (7) suffered reduced air pressure under the grate, (8) had increased number of fires in the siftings hoppers, (9) the reduced production of steam, etc.

This report mentions at several places that management's emphasis is on energy production. Considering the local situation in Zurich, this emphasis and the resulting economics seem proper. Apparently the marginal revenues exceed marginal repair costs when the system is moderately overloaded. This emphasis has therefore been contributory to some of the Units #1 and #2 problems. The original contract specified operation at the"continuous maximum load". The term was never clearly defined as to whether this meant "peak" or "average" or "maximum average load over the long running time".

Plant officials interpreted the rated 28 tonnes of steam per hour to be the maximum average load over the long-running time. Von Roll had, however, designed the plant assuming that the 28 tonnes of steam would be permissible for short periods as a holdable peak--but not for continuous operation.

Going back to the energy emphasis, plant people began a campaign to increase the volume of high calorific value industrial waste. The vendor claimed that (to paraphrase), "It was not fair to ask Von Roll to build a unit for 1,200-1,500 Kcal/kg refuse and then purposely try to load it with high calorific value refuse at 2,200-2,400 Kcal/kg."

The experience at Hagenholz and other similar experiences in Europe have sensitized system designers to push for an accurate current estimate of calorific values. More searching for accurate forecasts of calorific values 10, 20, and 30 years, hence, is needed as well.

The concern about Hagenholz Units #1 and #2 resulted in the design of a later unit at Hamburg:Borsigstrasse to be over-compensated. So much heat was extracted by the boiler that plant operators would worry about keeping the refuse properly burning. The writers now believe that all parties involved have carefully studied the parameters and that such problems will not recur at future installations--if designers and system purchasers will respect the calorific value of waste.

The Hagenholz full story will not be described in this report. Contracts, guarantees, politics, personalities, etc. could be the subject of a book and are not that relevant to this report. The item that is relevant is:

> "Learn the Present Composition of Waste and Estimate Future Trends".

Zurich's Philosophy for Unit #3. The technical problems experienced in Units #1 and #2 and the inability of the city and Von Roll to agree and then resolve the problems led to a prejudiced view of the firm for Unit #3. By 1970, other firms had improved their technologies and reputations.

The city opened prebid discussions to all vendors.

One official explained the city's philosophy that "this plant is not at a price but rather the city asked what can we build that will be most reliable". Another comment was: "The biggest (most important) thing is the grate".

Another philosophical comment, "Some people spend so much (money) on architecture...and then skimp on the (furnace/boiler) equipment. (Another plant) has a very nice entrance but can't make money".

They wanted "maximum reliability with minimum maintenance, a 4,000 hour guarantee, a minimum of 1-1/2 m^3 wastewater (per ton of refuse?), particulate emissions under 75 mg/Nm^3", etc.

Three bids were received: Martin, Von Roll, and VKW. The VKW chute-to-stack bid of S.Fr. 9,000,000 was lower than the S.Fr. 11,430,000 bid of Martin. Yet Martin was chosen due to the city's confidence in Martin's ability to produce an excellent system.

Building Unit #3. The result of this close collaboration on details is a unit that is one of the finest in Europe. Construction was finished in the early fall of 1973. There were no appreciable construction delays. The bid was fixed-price and there were no appreciable financing problems.

Next System Under Construction (Josefstrasse). Once the Martin Unit #3 had successfully passed its 4,000 hour compliance test in 1973, the city began discussions about replacing the second generation (1927-1976) Josefstrasse plant with a third generation Martin plant. This plant is now (1977) under construction at the original site.

The Hague

In 1919, the city built an incinerator but it was met by a storm of protest by those favoring utilization of wastes for recovery of land from the sea. As a result, on June 18, 1929, an agreement was reached whereby the incinerator continued to operate at a low rate but a distant landfill site was selected.

Later and for over 30 years, refuse from The Hague was sent by rail to a landfill and compost plant at Wijster in the region of Drente, 200 km (120 mi) away in the northeast part of Holland. Other cities, such as Amsterdam, also sent refuse to Wijster, which had the largest compost plant in Holland. Much of the compost was sold in 5 and 10 kg (11 to 22 lb) sacks. The dedicatory brochure for The Hague plant, published in March, 1968, stated that from the opening of the Wijster site on February 23, 1932, until the end of 1967, 154,984 rail car loads of refuse from The Hague were shipped to Wijster.

However, the cost of the long rail haul increased over the years and the demand for compost for land reclamation decreased. Accordingly, a study was begun on alternate methods for refuse disposal. In 1958, the conclusion was reached that a modern waste-burning facility should be planned. The planning extended from 1960 through 1964 in cooperation with the "Gemeentelijk Eneregiebefrif" (municipal utilities). One of the principal considerations was the need to meet high hygienic standards and to avoid nuisance factors inherent in other solutions. At the time when the decision was made, fuel prices were high, and the possibility to recover heat energy from refuse promised attractive revenues. This led to the combination of combustion and power generation. The final plant design included a total of four furnace-boiler units with an incineration capacity of 360 tonnes (400 tons) per day each. In November, 1964, the order was issued for three of them. The first three began operation in January, 1968.

Dieppe (Brive and Deauville)

Prior to the construction of the Dieppe plant in 1970-1971, the city and surrounding communities deposited their solid wastes in various uncontrolled landfills. Sewage treatment begun in 1934 was by primary settling only. Because of smokey fires at the landfills and the growing scarcity of available landfill area, discussions began in City Council late in 1967 on feasible means to upgrade their waste management methods. Composting was considered but not pursued because of the lack of assured local markets for the product. District heating was considered but only two factories in the vicinity could have used the steam. They would have a lower summer demand. Electricity generation was discussed but Electricite de France could not guarantee revenue for the electricity produced.

M. Jean Fossey, who is now Plant Manager, was, at the time of the discussions, a member of City Council. M. Marchand, then Director General of Technical Services for the City of Dieppe, became interested in the patented process developed by Von Roll, Ltd. This process uses the heat in steam from waste-fired boilers to partially dry sewage sludge in vertical thin film dryers and then to burn the sludge with the refuse. A decision was made in November, 1968, to build a steam generating refuse burner to begin operation in about 18 months or about May, 1970. Also, in April, 1969, it was decided to build, adjacent, a modern wastewater treatment plant to begin operation about April, 1971. The plants were sized for a community of about 48,000 people producing refuse and 40,000 people producing sewage. INOR S.A. (Societe de Construction d'Usines d'Incineration d'Ordures Menagers), the Von Roll licensee in France for this type of combined system, was selected to build them. Because it was the first full-scale combined plant of this type, Von Roll offered it at an introductory price.

On the strength of the decision at Dieppe in 1969 to build this pioneering plant, the City of Brive in southern France, population 55,000, invited bids on a combined facility in late 1969. By December, 1970, eight qualified bids had been received at Brive. In July, 1971, INOR S.A. was awarded a contract for the refuse burner. Omnium d'Assainissement, a French water treatment firm, was given the contract for the wastewater plant. The Brive refuse burner began operating in September, 1973, 2 years after the Dieppe plant and the wastewater plant in February, 1975.

The plants are operated for the city under a 20-year contract with the group Thermical-INOR.

The prospect for clean handling of both solid and liquid wastes at Dieppe and Brive probably were an important guide to Deauville, which decided to follow suit. The new Deauville facility was built on the site of the old city sewage treatment plant. The Deauville wastewater plant began operating in 1974 and the refuse burning plant early in 1976.

Gothenburg

Background. Prior to 1971, about 10 percent of the refuse disposal in the region was handled in 10 small local incinerators, seven of which recovered heat for district heating and the rest went to uncontrolled landfills. Air pollution from the incinerators was sometimes a problem. In 1955, discussions began of better ways of doing it. The concensus developed that a central facility would be desirable but siting was difficult. At one point, consideration was given to building some large landscaped hills of refuse as is now being done at the Hogdalen plant just south of Stockholm.

Mr. Bengt Rundquist wrote in 1972:

> "According to a special report on refuse prepared by the Greater Gothenburg Cooperation Committee in 1965, the 23-member districts formed a community of interests, Goteborgsregionens avfallsaktiebolag=GRAAB, with the task of solving associated problems.
>
> "The responsibilities of the districts and the regulations governing cooperation were laid down in a consortial agreement valid for a period of 30 years. The agreement describes the method whereby expenses shall be calculated, stipulates that costs for refuse treatment shall be the same throughout the region when the refuse is deposited at the incineration plant or any of the transfer stations, and how the shares amount to 4.5 illion kronor and the bonds amounting to 120 million kronor shall be distributed."
>
> "GRAAB also played a leading part in constructing GRAAB-KEMI, a receiving station for chemical wastes. This consists of a chemical storage, toxic storage, and an oil-reception plant. Furthermore, a wet chemical line was planned with the task of treating diluted solutions and those chemicals which are unsuitable for storage. The wet chemical line will form the basis for decisions on the region's own treatment plants. The operation of this reception station is taken care of by a subsidiary company, Slamsugningsaktiebolaget. This company has equipment for work in practically the entire chemical refuse sector. Detailed discussions were held with the Gothenburg Cleaning Department on the company's cooperation within the monopoly as a whole, which began to operate the Gothenburg district in January, 1973."
>
> "GRAAB was also commissioned to produce a cremation furnace for dead animals and a reception station for car scrap and metal waste. There is no separation of metal from the residue."

Although at the beginning of the discussions, 36 communities were involved, later consolidation of communities, which have been nationwide, reduced the number first to 23 then to 13, and now to nine large communities--these are all involved in GRAAB. Some of these extend partly into other counties. They have ownership in the entire system as follows:

	Shares	Percent
Ale	1,530	3.4
Goteborg	33,396	74.2
Harryda	762	1.7
Kungsbacka	1,129	2.8
Kungalv	2,034	4.5
Lerum	1,101	2.4
Molndal	3,066	6.8
Partille	1,551	3.5
Ockero	321	0.7
TOTAL	45,000	100.0

The nine communities are represented on a Board of Directors, which meets 10 times a year. A working committee of the Board meets about twice a month.

Beginning of the Savenas Facility. Eight bids were received in 1969 for the Savenas plant. Von Roll, Ltd. was selected because, although it was not the lowest bidder, it appeared to have experience with many similar large plants and had built or was building plants at Linkoping, Bollmora, and Umea in Sweden.

In 1965, the estimated price was 65 million s. kr. The contract was signed in October, 1969. By the time the plant and its ancillary stations were built in 1972, the total cost had risen to 120 million s. kr. This included five transfer stations and the Tagene landfill for residue and sewage sludge. Three boiler-furnace units were installed with building space provided for a fourth unit.

Inflation was the primary cause of the increase in cost although the national environmental authorities caused some increase by requiring some enlargement of pollution control equipment. GRAAB management feels that 88 percent of the increase was beyond their control. For example, unexpected clay under the site required 3,000 m^3 more piling than expected. For this same reason, the refuse pit is not as deep as planned.

Normal plant operation begain on March 1, 1972. It operates 7 days/week.

Uppsala

In the 1950's, a compost plant operated at Hovgarden. However, a market for composted material could not be maintained. Thus, in 1960, there was sufficient pressure to find another solid waste disposal alternative.

The Uppsala waste-to-energy plant developed as part of a much larger and integrated environmental improvement and energy conservation program that was started by the City Council in 1960. In that year, it was decided to construct a plant for the production and distribution of district heat. The plans also included a thermal power station, an installation for the production of electrical and thermal energy, and a waste-to-energy plant.

The first delivery of heat was in August, 1961, from a portable oil-fired boiler, and the first permanent hot water generator at the

Kvarngarde Plant began operating in September, 1962. Since the expansion has materialized into a larger oil-fired hot water station in the Bolander Plant (built in three stages in 1965, 1968, and 1971) and into a peak load plant in Husbyborg (1975). Certain areas are still taken care of by portable oil-fired boilers until the expansion of the main network to these areas can be economically justified.

In the waste incineration plant, which began operating at Bolander in 1961, the steam produced is used to heat water for district heating. The initial installation of two furnaces rated at 3 tonnes/hour and supplying hot flue gas to two waste heat boilers was built in 1960 by Kochum-Landsverk and began operation in 1961. A third similar but larger (3.5 tonne/hour) was added in 1965. A fourth furnace system, burning 5 tonnes/hour and feeding a third boiler, began operation in 1970. This newer Unit #4 installation built by Bruun and Sorensen is the principal subject of our plant visit.

Two smaller incinerators burn biological wastes and contaminated dextrose solution from the Fortia-Pharmacia plant. The hot waste gases from the latter are mixed with those from the larger furnaces ahead of the waste heat boilers. The useful thermal energy recovered from the wastes, about 34 Gwhr (thermal) in 1975, is only a small part, 2.5 percent, of the total energy produced by the entire system, 1,373 Gwhr. However, its recovery results in a much more acceptable solution to the solid waste problem than the old landfills. Also, in the summer, a major fraction of the hot-water needs of the community are met with energy derived from the solid wastes.

The waste-to-energy plant was designed by the engineering staff of the Uppsala Thermal Power Company (Uppsala Kraftvarme AB). This is unusual for Sweden where normally the city engages a consulting engineering firm to design, purchase, and supervise construction.

In 1970, the volume of solid waste was becoming more than the existing refuse burning units could process, and the high calorific value industrial waste would overheat the furnace refractory. Therefore, the community decided to construct a pulverizer station at the old Hovgarden compost facility.

Horsens

In the early 1970's, the City Council of Horsens determined that the uncontrolled landfill then in use had to be replaced by an environmentally more acceptable method for disposal of solid wastes. Landfill fires and rats were objectionable. Accordingly, the city engineer visited 10 cities which had used various incineration systems to solve a similar problem.

At Horsens, composting had already been ruled out by an unsatisfactory experience with a modern composting system used from 1951 to 1965. From the start of its operation, assured markets for the product could not be maintained. Very little product was sold. In the last 5 years of operation, 1960-1965, none was sold.

In Denmark, well-managed landfills cost one-half to one-third as much to operate as incinerators. But in eastern Jutland, acceptable sites for new landfills are rare. Therefore, in 1972, the Council decided to build an incineration plant. A letter defining the designed system was prepared by the Economic Development Committee of Council and was sent to various vendors inviting their interest. As a result, definite bids were received from three Danish companies: Bruun and Sorensen, Volund, and Elsinor. Bruun and Sorensen, whose main office is in Aarhus only 40 km (25 mi) away, was the low bidder. The plant details and final price were then negotiated and the plant was built as a turnkey project.

In order to make use of some of the heat released by incineration, the plan included separate construction of a sewage treatment plant adjacent to the incinerator so that hot flue gas could be used to partially dry the digested sludge. Heat recovery for district heating was not added until 1977.

The decision in 1973 to build the plant was made solely by the Council and no referendum was required. However, on January 1, 1977, a new Danish law became effective requiring that city plans must now be available for citizen scrutiny and comment. The final decision, however, remains with City Council, subject then to approval by the regional council.

Initially, it was hoped to locate the plant near one of the three existing privately-owned district heating plants, but space was too confining and increased traffic there would have been difficult. The present ample site on a shallow, filled-in part of the Horsens Fjord is conveniently adjacent to the current landfill. Also adjacent is a chemical waste collection depot where such wastes are collected for shipment by barge to Denmark's nationally operated liquid and hazardous waste disposal plant at Nyborg, about 100 km (62 mi) southeast of Horsens.

As in many Danish communities, an important incentive toward clean alternatives to landfilling is the threat to groundwater quality from old, uncontrolled landfills. Also, since Denmark imports all of its energy, the recovery of energy from wastes has long been an important goal. The oil crisis of October, 1973, intensified the need for more waste-to-energy systems. At Horsens, additional refuse-fired heating plants are envisioned. Also, it is expected that in the future, to conserve energy, national legislation will require greater use of district heating. Some of this expansion will undoubtedly use refuse as fuel.

Copenhagen (Amager and West)

Waste-to-energy began in Copenhagen in the early 1930's with the 1932 commissioning of the two 144-tonne (158-ton) per day Volund grate/rotary kiln furnaces at Gentofte, each with a three-drum boiler as shown in Figure I-2. The steam was used to make electricity as specified by the city's Electrical Board. This construction was followed by two similar Volund units at Frederiksberg in 1934.

These two plants served Copenhagen well for 40 years. During that time, these plants had reached their capacity and excess refuse had to be landfilled both inland and on the sea coast. There is a large undeveloped area in the western part of Amager Island. This was basically low swamp land that has been filled in with both demolition debris and household refuse.

During the 1960's, when knowledge of landfill leachate damages became better known and when neighbors became upset over blowing trash,

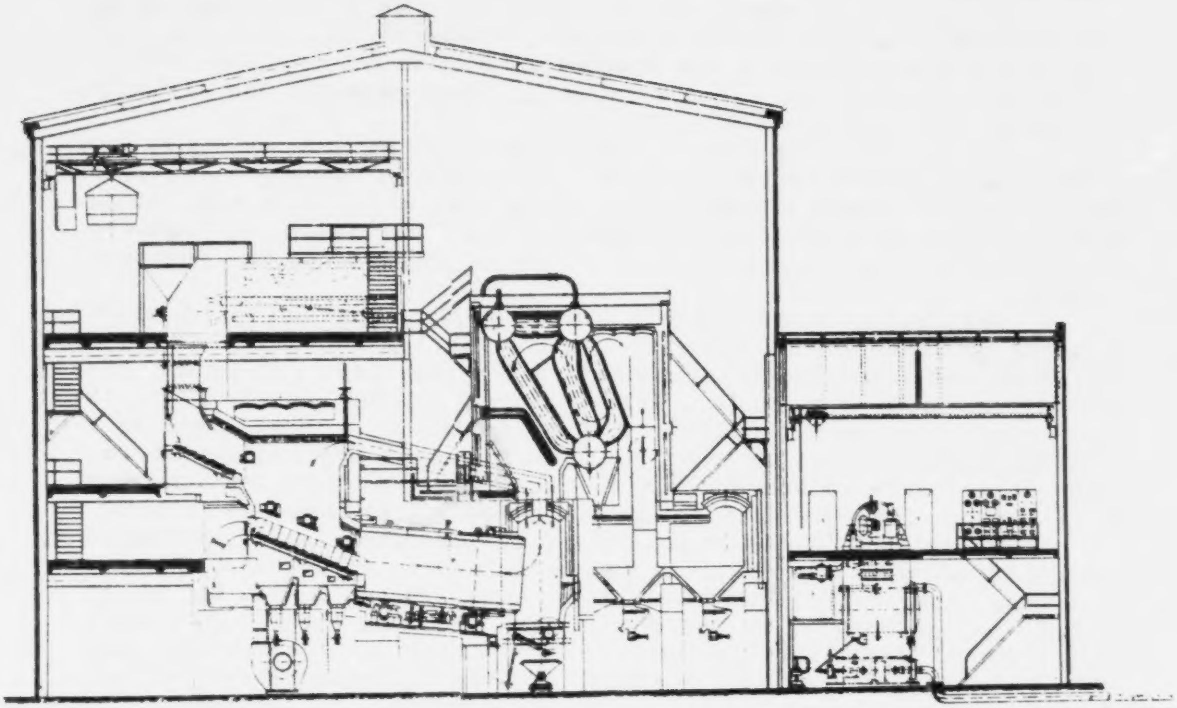

FIGURE I-2. FIRST VOLUND SYSTEM BUILT AT GENTOFTE IN 1932 AND DECOMISSIONED 40 YEARS LATER IN 1972

etc., local citizen groups on Amager Island got the attention of elected officials.

For a time, it seemed that each community wanted to independently solve its solid waste disposal problems. Finally, one of the Island communities decided to build a resource recovery plant. Others soon followed. Eventually the City of Copenhagen joined in the development.

Incidentally, the excitement about Amager encouraged the residents west of Copenhagen to develop a similar system now called "Vest" or "West". Eventually, the Copenhagen Gas and Electric Company conducted a study that resulted in the recommendation that two new refuse-fired hot water generators be built to replace Gentofte and Frederiksberg.

Of note was that the competitive approach provided both organizations with a quantity discount if both purchased similar units. The competitors were:

- Heenan-Froud
- Martin
- VKW
- Volund
- Von Roll.

Officials remember that VKW, Volund, and Von Roll had the lowest single unit prices (i.e., nonquantity discount). Other excellent Volund plants in Denmark, the long history of successful operations at Gentofte and Frederiksberg, the low (maybe not the lowest) single plant price, the quantity discount, and the Volund headquarters being nearby all contributed to the decision favoring Volund.

Construction at Amager began in 1965 with 2 year's of sea and earth reclamation. Plant construction began in 1967 and was completed in 1970. Construction at Amager preceded work at West by 9 months.

There was just enough operating time at Amager to the benefit of last minute improvements at West. The refuse input cranes and the ash discharge equipment are just two examples.

Copenhagen:Amager is owned by the five communities it serves, as are listed in the "Organization and Personnel" section at the end of this report. Amager started operations with three 12-tonne (13.2 ton) per hour furnaces assuming 2,500 Kcal/kg.

Copenhagen:West is owned by the 12 communities it serves, as are also listed in the "Organization" section. West started operations in November, 1970, with three 12-tonne (13.2 ton) per hour furnaces assuming 1,500 Kcal/kg. Later in 1977, a fourth furnace rated at 14 tonnes (15.4 tons) per hour, assuming 2,500 Kcal/kg, was installed.

TOTAL OPERATING SYSTEM

General Comments

Many plants provided data in a massive form. Such data provides the opportunity to analyze the plant as a total operating system. Interrelationships and ratios can have more meaning if the data can be viewed together. Data is included on thermal and combustion efficiency, volume reduction, shut-downs, operating hours, tons of waste received, cooling water, steaminng rate, steam production, air pressure, availablity, etc. Data is presented without extensive analysis. System decision makers and designers are challenged to review the tables for enhancemet of a mature understnading of refuse fired energy plants.

Some of the material mentioned in this section is repeated in other relevant sections such as on boilers, energy utilization ash recovery, etc. Other material appears only here.

In several cases, the numbers given in interviews are different than those in the total operating system tables. These researchers have endeavored to resolve differences. However, many inconsistencies remain.

Total Operations at Visited Systems

Baden-Brugg

Table J-1 from the plant statistical statement shows the energy production figures for 1975 and 1976. The average plant evaporation rate for 1976 was 2.26 tonne steam per tonne refuse. Assuming the average LHV of the refuse was 2285 kcal/kg (9399 kJ/kg) (4113 Btu/lb) this corresponds to an average steam generating efficiency of 55 percent.

The electrical energy produced averaged 440 kwh/tonne. This corresponds to a generating efficiency of 16 percent.

The amount of thermal energy supplied to the adjacent plants was small and was not recorded.

The volume reduction of the refuse was estimated to be about 85 percent. The weight reduction achieved is about 37-38 percent.

The plant, which began operation in November 1970, has had no major shutdowns since the initial problems with tube wastage in 1973 after 11,000 hours operation. Normally, maintenance can be done during the regular weekend shut-down. Every 6 months the plant is down for one (1) week for major overhaul.

Except for the routine downtime, operation was 99.1 percent ofthe time in 975 and 96.7 in 1976.

Table J-2 is a summary of weekly plant operating data for the 9 weeks May 2, 1976, to July 4, 1976, provided from routine plant records. The annual data similar to this table will be discussed in later sections of the report. It is shown together here in facilitate the readers analysis of processing and production rates. It is of interest that the total waste burned never quite reached the normal plant capacity for a 5-day week: 1000 tonnes. However, it nearly attained that rate in almost half of the weeks. But the maximum power generator capacity of 5.2 mw. The cause of this reduction was not determined.

The evaporation rate, tons steam per ton of waste was normal and ranged from 2.16 to 2.66. The calculated heat value of the refuse 2115 to 2538

TABLE J-1. ENERGY GENERATION RATES AT BADEN-BRUGG FOR 1975 AND 1976 (FROM PLANT STATISTICAL STATEMENT)

		1975	1976
Operating time of both furnaces	h/ year	10,598	9,750
Operating time of turbine	h/ year	6,132	5,467
Average furnace capacity	mt/h	3.72	3.97
Average boiler capacity	mt/h	8.41	8.60
Average turbine capacity	kw	2,833.2	2,943.0
Average coefficient of evaporation	t/t	2.26	2.16
Average heat value of waste	kcal/kg	2,285	2,165
Electrical energy per tonne of waste	kwh/mt	440	415
Total electrical production	kwh x 10^6	17.37	16.09
Electricity supplied to AEW, ARA, Fairtec	kwh x 10^6	14.85	13.79
Electricity internally generated and used	kwh x 10^6	2.52	2.30
Electricity purchased from AEW	kwh x 10^6	0.20	0.20
Total internally used electricity (without losses)	kwh x 10^6	2.72	2.50
Electricity consumption per tonne of refuse	kwh/mt	68.91	64.44

TABLE J-2. BADEN-BRUGG WEEKLY OPERATING SUMMARY MAY 2 TO JULY 4, 1976

			Week of the Year 1976							
			20	21	22	23	24	25	26	27
Amount of Waste Received Tonnes	t	817.21	803.37	871.37	720.82	993.13	767.00	685.64	798.64	765.14
Waste Burned-Furnace 1	t	472.83	439.54	469.94	300.63	482.13	382.84	453.38	433.75	406.70
" " " 2	t	468.43	446.99	476.15	300.37	472.28	370.94	451.08	-	417.20
" " " Total	t	941.26	886.45	946.09	601.00	954.41	753.78	904.46	433.75	823.90
Amount of waste oil received	t	0.68	-	-	-	2.04	0.84	1.26	1.32	0.58
Furnace residue, wet	t	358.96	332.74	347.84	274.76	368.14	309.02	354.34	204.72	279.18
Furnace 1, operating time	hr	127	123	123	78	126	100	124	125	124
" 2, " "	hr	126	124	122	78	126	101	124	-	124
Turbine operating time	hr	12.3	121	119	75	123	97	121	119	122
Electricity delivered to the network	kw/hr	356025	379650	308700	188125	318300	263100	321000	118050	326325
" consumed from the network	kw/hr	12975	19725	2850	34725	24300	15375	17325	18000	16500
" produced	kw/hr	442000	411000	401000	248000	410000	336000	415000	188000	420000
" consumed internally	kw/hr	65500	66900	64000	45800	65000	52600	66700	43300	65000
" to sewage plant from network	kw/hr	9000	14000	14000	31000	13000	11000	12000	13000	13000
" " " " " this plant	kw/hr	25900	31400	33000	16700	37300	25800	32800	30700	30100
Total electricity to sewage plant	kw/hr	34900	45400	47000	47700	50300	36800	44800	43700	45100
Process water	m^3	22	29	21	9	24	22	24	31	27
Cooling water	m^3	167	162	167	197	124	165	249	226	279
Total water consumption	m^3	189	197	188	222	198	187	273	297	306
Electrical consumption/ton waste	Wh/tK	470	464	424	413	430	446	459	433	510
Calculated heat value of refuse	kcal/kg	2344	2354	2147	2128	2115	2235	2230	2538	2598
Average generation rate	kw	3593	3397	3370	3307	3333	3464	3430	1580	3443
Average furnace burning rate	t/h	3.85	3.66	3.86	3.85	3.79	3.75	3.65	3.47	3.32
Average boiler steaming rate	t_D/h	8.92	8.64	8.48	8.38	8.20	8.57	8.59	8.31	8.82
Steam production ratio	t_D/tK	2.40	2.40	2.20	2.18	2.16	2.29	2.35	2.40	2.66

kcal/kg (8855 kJ/kg to 10,877 kJ/kg) (3807 to 4676 Btu/lb) also appears to be typical of European waste.

Duesseldorf

The product of this plant is high-pressure, high-temperature steam. In 1975 it delivered 58.1 percent of its rated steaming capacity. Actually since the plant design philosophy is to have one boiler always in reserve this output was nearer to 70 percent of nominal operational capacity. Considering the inherent difficulty involved in handling wastes as fuel with all these problems the neat and well-maintained appearance of this plant and its grounds, 70 percent of nominal capacity is excellent. The performance is even more remarkable in terms of the pioneering nature of the plant, this particular type of stoker was invented only 16 years ago and this is the first large plant ever built using this principle.

Table J-3 is a summary of the year's operating data for 1976 as printed from the data storage and analysis steam.

Paris: Issy

Percent availability is a definitional matter where one must pay careful attention to the numerator and denominator as displayed in Table J-4.

Hamburg: Stelling-Moor

Table J-5 presents gross operating figures for December, 1976, and the complete years 1976 and 1975.

Tables J-6 and J-7 follow and respectively present detailed operating readings taken every 2 hours on November 4, 1976, and April 2, 1977.

The operation recording and the chart dated November 4, 1976, concern Boiler No. 1, after cleaning and at the beginning of a new period of continuous operation.

The operation recording and the chart of April 2, 1977, concern Boiler No. 1 also, but after 3,567 hours of continuous operation.

Zurich: Hagenholz

Any visitor to the Zurich-Hagenholz plant will soon be discussing the Von Roll #1 and #2 units and the Martin #3 unit. This report is intended to fully discuss the Martin #3 unit. Nevertheless, we feel that certain operating data for all three units should be presented, but in proper perspective.

To repeat from a previous section, most of the problems of units #1 and #2 derived from a design for "somewhat over 1000 kcal/kg (1800 Btu/pound) waste" instead of waste actually over 2000 kcal/kg (3600 Btu/pound) as has been the case in the 1970's.

Table J-8 presents some operating figures for 1974 which reflect poorly on units #1 and #2. But, as mentioned before, 1974 was the year for major overhauling that could not be accomplished before.

TABLE J-3. DUESSELDORF WASTE-BURNING FACILITY--OPERATING RESULTS - 1976

Waste Input		
Residential Waste	180,462.80	Tonnes
Industrial Waste	65,795.35	Tonnes
Bulky Waste (Residential and Industrial)	25,250.79	Tonnes
Rubbish	10,844.80	Tonnes
Waste Oil	1,831.54	Tonnes
Total	284,185.37	Tonnes
Heating Oil	20.81	Tonnes
Consumption		
Waste	284,185.37	Tonnes
Heating Oil	3.40	Tonnes
Storage		
Waste	2,475.00	Tonnes
Heating Oil	26.84	Tonnes
Heat Value		
Waste	1,815.98	kcal/kg
Heating Oil	10,155.03	kcal/kg
Sulfur		
Heating Oil	0.43	Percent
Wet Residue		
Fine	78,706.30	Tonnes
Discarded	19,650.28	Tonnes
Total Residue	98,356.58	Tonnes
Total Residue Shipped	97,641.58	Tonnes
Storage	935.00	Tonnes
Residue Analysis		
Water	18.89	Percent
Combustible	5.03	Percent
Scrap Iron		
Total	8,492.42	Tonnes
Bulky Scrap	531.51	Tonnes

TABLE J-3. (Continued)

Electricity Consumption		
Total Received	14,521.00	MWH
Maximum Electrical Demand	2,445.00	KW
Consumption		
City Water	99,253.00	Cubic Meter
Well Water	507,671.00	Cubic Meter
Total Water	606,924.00	Cubic Meter
Time of Operation of all Boilers	30,963.00	Hours
Waste Feed		
Number of Crane Loads Charged	125,939.00	
Live Steam		
Pressure	81.26	Bar
Temperature	471.90	°C
Amount	592,265.00	Tonnes
Enthalpy of Steam	795.06	kcal/kg
Enthalpy of Feedwater	130.71	kcal/kg
Flue Gas Temperature	270.00	°C
Oxygen (O_2) Content		
Left Side of Furnace	8.88	Percent
Right Side of Furnace	8.88	Percent
Air Temperature		
Ambient	11.00	°C
Entering Preheater	25.00	°C
Leaving Preheater	87.00	°C
Heat Balance		
Live Steam	470,885.32	Gcal
Exhaust Gas	94,749.74	Gcal
Combustible in Residue	18,673.44	Gcal
Sensible Heat in Residue	12,702.76	Gcal
Piping and Radiation Loss	13,322.98	Gcal
Total	610,334.24	Gcal

TABLE J-3. (Continued)

Heat Input		
Heat in Feedwater	77,414.96	gcal
Heat in Combustion Air	16,810.26	gcal
Heat From Heating Oil	34.53	gcal
Heat From Waste	516,074.50	gcal
Boiler Efficiency	73.83	Percent
Energy Losses		
Exhaust Gas	17.78	Percent
Unburned Combustible	3.50	Percent
Sensible Heat in Residue	2.38	Percent
Piping and Radiation Loss	2.50	Percent
Consumption and Operating Rates		
Heating Oil	0.11	kg/hour
Waste (aver. per unit operating)	9.18	tonnes/hour
Crane Lift Rate	2.26	tonnes/grab
Heat Release	16.67	Gcal/hour
Live Steam Rate		
Total	19.13	tonnes/hour
Produced From Oil	1.34	kg/hour
Produced From Waste	19.13	tonnes/hour
Production Rates		
Steam Per Unit Fuel	2.08	kg/kg
Steam Per Unit Waste	2.08	kg/kg
Steam Per Unit Oil	12.19	kg/kg
Residue Per Unit Waste	0.37	kg/kg
Total Water Consumption	2.14	Cubic Meter/tonne
Electricity Consumption		
Per Tonne Total Waste	51.10	kwh/tonne
Per Tonne Steam	24.52	kwh/tonne
Steam Sold	564,091.00	Tonnes

TABLE J-4. AVAILABILITY OF ISSY'S TOTAL SYSTEM

	Month of December		Year of	
	1976	1975	1976	1975
Hours of operation (4 furnaces)	2,608	2,752	29,053	29,428
Tons of waste burned per furnace/boiler per hour	20.4	17.4	19.9	19.1
Availability of furnace/boiler	2,795	2,818	29,723	30,291
Maximum hours available	2,976	2,976	35,040	35,040
Actual operation availability	87.6	92.5	82.9	84.0
Furnace availability	93.9	94.7	84.8	86.4
Hours of scheduled downtime	-	64	2,376	3,126
Delayed report carryover from 1975	-	-	307	-
Hours of unanticipated downtime	181	94	2,730	1,623

Source: TIRU statistics

TABLE J-5. GROSS OPERATING FIGURES FOR DECEMBER 1976 AND THE COMPLETE YEARS 1976 AND 1975 FOR HAMBURG: STELLINGER-MOOR

	December 1976	Year 1976	Year 1975
Truck Deliveries			
Household trucks (number)	3,233	38,754	49,686
Industrial trucks (number)	198	3,542	4,488
Total trucks (number)	3,431	42,296	54,174
Waste Input			
Household waste (tonnes)	14,469	161,617	216,848
Industry waste (tonnes)	881	14,899	19,125
Miscellaneous waste (tonnes)	3,487	18,748	2,801
Total waste (tonnes)	18,837	195,264	238,774
Boiler 1			
Waste input (tonnes)	9,535	98,762	118,412
Steam generated (tonnes)	22,391	217,706	231,028
Steam / waste (tonnes / tonnes)	2.35	2.20	1.95
Operating time (hours)	744	7119	7264
Boiler 2			
Waste input (tonnes)	8,640	101,794	115,828
Steam generated (tonnes)	19,888	210,286	226,992
Steam / waste (tonnes / tonnes)	2.30	2.07	1.86
Operating time (hours)	665	7311	7505
Boilers 1 and 2			
Waste input (tonnes)	18,175	200,556	234,240
Steam generated (tonnes)	42,279	427,992	458,020
Steam / waste (tonnes / tonnes)	2.33	2.13	1.96
Operating time (hours)	1409	14430	14769
Fuel Oil #2			
Delivery (liters)	10,016	98,934	83,004
Consumption (liters)	16,940	104,398	83,183
Turbine 1			
Steam consumed (tonnes)	--	110,170	306,258
Operating time (hours)	--	2,187	6,059
Turbine 2			
Steam consumed (tonnes)	41,448	310,505	137,090
Operating time (hours)	744	6,669	2,872
Turbines 1 and 2			
Steam consumed (tonnes)	41,448	420,675	443,348
Operating time (hours)	744	8,856	8,931
Power Supply			
Generator 1 (kwh)	--	19,478,100	55,043,300
Generator 2 (kwh)	6,900,500	49,761,000	23,012,000
Generator total (kwh)	6,900,500	69,239,100	78,055,300
Purchased power (kwh)	--	196.350	209,550
Total power available (kwh)	6,900,500	69,435,450	78,264,850
Power Use			
Sewage treat plant (kwh)	417,582	4,308,709	3,963,977
Internal plant consumption (kwh)	1,295,168	12,228,467	12,492,885
High Demand Peak Load(kwh)	1,306,800	13,224,750	15,467,100
Low Demand Base Load-weak-peak (kwh)	3,875,850	39.616,500	46,333,650
Total power used (kwh)	6,395,400	69,378,426	78,257,612
Water Supply			
Purchase from Hamb. W.W. (m^3)	1,303	15,276	12,394
Well fed cooling water (m^3)	14,938	179.855	177.859
Water Uses			
Consumption of H.W.W. (m^3)	93	1,810	645
Change in stock of H.W.W. (m^3)	--	254	247
Sanitary uses of H.W.W. (m^3)	710	7,582	7,429
H.W.W. to treatment station (m^3)	500	5,884	4,320
Well water to treatment station (m^3)	7,884	78,777	21,031
Well water process water (m^3)	7,054	101,332	157,075
Boiler feedwater addition (m^3)	976	12,179	22,379
Residuals			
Ash for roadbuilding (tonne)	2,316	73,251	80,756
Big scrap iron (tonne)	663	11,737	14,129
Small scrap iron	369	3,837	6,268
Stumps and tires landfilled			
Total recycle residuals (tonne)	3,348	83,825	101,153

Source: Stellinger-Moor plant operations staff T3/R56 Betriebsergenbnisse de. MUA II January 11, 1977.

TABLE 7-6. DETAILED OPERATING STATISTICS FOR NOVEMBER 4, 1976
BOILER NUMBER 1 AT HAMBURG: STELLINGER-MOOR

		Shift #1				Shift #2				Shift #3			
		07	09	11	13	15	17	19	21	23	01	03	05
Steam production	T/h	30	32	34	32	30	30	30	30	31	33	33	30
Steam temp. upstream injection spraying	°C	425	420	425	430	425	425	430	425	430	420	426	420
Injection Spraying	%	50	30	40	50	50	40	45	45	45	25	45	30
Total air	$M^3 10^3$	40	43	43	42	40	40	40	50	50	45	40	42
Percent of primary air	%	42	42	42	45	45	45	45	45	45	45	40	45
Comb. air temp.	°C	40	85	80	95	110	110	110	50	50	40	40	40
Oxygen content	%	25	25	25	25	8	16	8	10	10	10	9	10
Furnace roof temperature-left	°C	630	642	630	630	620	610	610	550	600	600	620	600
Furnace roof temperature-right	°C	650	670	650	650	630	620	630	610	610	620	650	620
Superheater temperature	°C	510	510	480	400	475	470	480	480	480	475	475	470
Convection section temperature	°C	405	405	370	370	365	370	380	380	380	370	370	370
Economiser exit	°C	280	270	260	265	260	245	240	250	250	260	250	260
EGR precip. exit	°C	265	260	250	250	245	240	240	240	240	250	240	250
Underfire air pressure Right Zone 1	mmWs	70	70	40	80	75	80	60	70	70	70	100	80
Underfire air pressure Right Zone 2	mmWs	50	50	50	60	50	50	70	60	55	60	50	50
Underfire air pressure Right Zone 3	mmWs	65	60	30	20	30	30	40	40	40	30	30	25
Underfire air pressure Right Zone 4	mmWs	11	0	0	- 5	0	0	15	10	10	20	20	15
Underfire air pressure Right Zone 5	mmWs	-10	-10	-10	-10	-10	-10	-10	-10	-10	0	- 5	-10
Underfire air pressure Right Zone 6	mmWs	-15	-20	-20	-20	-20	-20	-15	-15	-10	-15	-15	-15
Underfire air pressure Left Zone 6	mmWs	-15	-11	-20	-12	-15	-20	-15	-15	-15	-10	-15	-15
Underfire air pressure Left Zone 5	mmWs	-10	-10	-10	-10	-10	-10	-10	-10	-10	0	- 5	- 5
Underfire air pressure Left Zone 4	mmWs	11	- 5	- 5	0	10	0	15	10	10	15	15	15
Underfire air pressure Left Zone 3	mmWs	30	30	30	45	30	30	40	30	30	30	40	35
Underfire air pressure Left Zone 2	mmWs	50	60	60	70	60	70	65	50	55	60	55	50
Underfire air pressure Left Zone 1	mmWs	90	100	100	100	100	100	90	90	90	100	100	90
Secondary air pressure-front wall	mmWs	400	400	400	400	400	350	420	420	420	420	420	420
Secondary air pressure-back wall	mmWs	500	500	500	500	500	470	520	520	520	520	520	520
Furnace atmospheric pressure	mmWs	6	6	6	6	6	6	6	6	6	6	6	6
Superheater atmospheric pressure	mmWs	2	5	5	10	5	5	10	8	5	10	10	5
Convection section atmospheric pressure	mmWs	10	10	10	20	15	15	15	15	15	15	10	10
Schlavo economizer	mmWs	30	25	25	30	25	30	30	30	30	40	30	30
EGR electrostatic precipitator	mmWs	35	35	35	35	35	35	35	35	35	40	30	30
ID suction fan (rpm)	u/min	400	390	350	410	340	350	350	360	350	440	380	
Furnace control set	%	62	63	62	62	60	60	60	60	60	60	60	60
Indi. control desk	%	75	75	75	80	80	80	80	80	80	80	80	80
Top feeder ram	0-10	77	77	77	77	77	77	77	77	77	77	77	77
Lower feeder ram	0-10	77	77	77	77	77	77	77	77	77	77	77	77
Stroke of upper stoker (feeder)	mm	200	200	200	200	200	200	200	200	200	200	200	200
Stroke of lower stoker (feeder)	mm	600	600	600	600	600	600	600	600	600	600	600	600
Stoker speed	0-12	8	8	8	92	92	92	92	92	92	92	92	92
Indic. control desk	%	50	50	50	60	60	60	60	60	60	60	60	60
Setting of final roller	0-12	4	4	4	4	4	4	4	4	4	4	4	4
Setting of vibrating slag conveyor	0-10	6	6	6	6	6	6	6	6	6	6	6	6

TABLE J-7. DETAILED OPERATING STATISTICS FOR APRIL 2, 1977
BOILER NUMBER 1 AT HAMBURG: STELLINGER-MOOR

		Shift #1				Shift #2				Shift #3			
		07	09	11	13	15	17	19	21	23	01	03	05
Steam production	T/h	27	25	27	26	27	28	27	24	25	25	26	25
D. Temp. V. Kuhler	°C	440	435	430	430	430	430	430	425	425	430	435	435
Injection spraying	%	55	50	35	40	50	45	40	35	42	36	40	45
Total air	$M^3 10^3$	38	35	35	35	35	35	36	38	38	37	37	36
Percent to primary air	%	25	25	25	25	25	25	25	25	25	25	25	25
Luft temp. n. Luvo	°C	85	85	85	90	80	80	90	90	90	90	90	90
Oxygen content	%	10	105	105	10	10	10	10	10	95	10	10	10
Furnace roof temperature-left	°C	770	740	740	740	760	770	760	720	730	730	730	230
Furnace roof temperature-right	°C	710	760	740	740	750	760	750	700	720	720	720	720
Superheater temperature	°C	600	580	580	590	590	590	590	570	590	600	595	600
Convention section temperature	°C	520	520	510	510	525	525	530	520	530	540	525	525
Schlovo	°C	345	345	325	330	340	340	340	335	345	350	345	345
EGR	°C	335	335	320	325	325	320	320	320	325	335	330	335
Underfire air pressure Right Zone 1	mmWs	50	50	55	50	60	60	65	50	50	60	60	55
Underfire air pressure Right Zone 2	mmWs	60	60	60	60	60	60	60	60	60	65	65	70
Underfire air pressure Right Zone 3	mmWs	35	30	30	30	30	30	30	30	30	35	35	35
Underfire air pressure Right Zone 4	mmWs	- 5	- 5	0	0	0	- 5	- 5	- 5	- 5	0	- 5	- 5
Underfire air pressure Right Zone 5	mmWs	-10	-10	-10	-10	-10	-15	-15	-10	-10	-10	-10	-10
Underfire air pressure Right Zone 6	mmWs	-20	-20	-15	-15	-15	-20	-20	-15	-15	-15	-15	-20
Underfire air pressure Left Zone 6	mmWs	-20	-20	-20	-15	-20	-20	-20	-20	-20	-15	-20	-20
Underfire air pressure Left Zone 5	mmWs	-10	-15	-10	-10	-10	-15	-10	-10	-15	-10	-15	-15
Underfire air pressure Left Zone 4	mmWs	- 5	-10	- 5	- 5	- 5	- 5	- 5	- 5	- 5	- 5	- 5	- 5
Underfire air pressure Left Zone 3	mmWs	40	30	40	35	40	35	35	30	40	40	40	40
Underfire air pressure Left Zone 2	mmWs	60	60	60	60	65	60	60	55	60	60	65	60
Underfire air pressure Left Zone 1	mmWs	60	65	60	50	50	50	45	40	40	40	40	40
Secondary air pressure-front wall	mmWs	400	400	400	400	400	400	400	400	400	400	400	400
Secondary air pressure-back wall	mmWs	500	500	500	500	500	500	500	500	500	500	500	500
Furnace atmospheric pressure	mmWs	6	6	6	6	6	6	6	6	6	6	6	6
Superheater atmospheric pressure	mmWs	10	10	10	10	10	10	10	10	10	10	10	10
Convention section atmospheric pressure	mmWs	20	15	15	15	20	20	20	20	20	20	20	20
Schlavo economizer	mmWs	40	40	45	40	45	45	45	45	50	45	45	40
EGR electrostatic precipitator	mmWs	65	60	60	60	70	60	65	60	70	65	85	60
ID suction fan (rpm)	u/min	600	570	540	580	580	570	550	540	570	590	600	580
Furnace control set	%	72	72	73	73	73	73	73	73	73	73	72	72
Indi. control desk	%	80	80	80	80	80	80	80	80	80	90	80	80
Top Feeder ram	0-10	7	7	7	7	7	7	7	7	7	7	7	7
Lower Feeder ram	0-10	68	68	68	68	7	7	7	7	7	7	7	7
Stroke of upper stoker (feeder)	mm	220	220	220	220	210	210	210	210	210	210	210	210
Stroke of lower stoker (feeder)	mm	600	600	600	600	600	600	600	600	600	600	600	600
Stoker speed	0-12	8	8	8	8	8	8	8	8	85	85	85	85
Indic. control desk	%	60	60	60	60	60	60	60	60	65	65	65	65
Setting of final roller	0-10	5	5	5	5	5	5	5	5	5	5	5	5
Setting of vibrating slag conveyor	0-12	7	7	7	7	7	7	7	7	7	7	7	7

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TABLE J-8. COMPARISON OF ZURICH-HAGENHOLZ INCINERATOR PERFORMANCE, 1974

Incinerator boiler #	#1	#2	#3
Make of incinerator	Von Roll	Von Roll	Martin
Maximum throughput of solid waste Sh.T/D	286.52	286.52	521.0
Maximum Burning Rate Sh.T/D	11.93	11.93	21.7
Average Burning Rate Sh.T/D	9.18	9.18	15.7
Average Performance Rate %	76.90	60.70	72.5
Total Operating Hours Hr/Yr.	4,766.00	4,561.00	7,004.0
Availability %	54.40	52.10	80.0
Average Steam Output Sh.T/Hr	23.675	18.672	40.5
Rated Steaming Capacity Sh.T/Hr	28.00	28.00	42.1
Average Steam Output Rate %	48.60	66.70	96.4

Source: Information obtained from data given by Mr. Max Baltensperger, Director, Department of Streets and Sanitation, City of Zurich.

By 1976, all three units were operating on a more normal schedule as shown in Table J-9. Figures are also presented for the entire Sanitary Park complex including the following buildings and energy customers.

- Car and truck repair shop (1,000,000 SF ($400,000) spare parts in basement
- Office building
- Workers social hall and cleanup area
- Truck garage for storage
- Rendering plant
- FBW
- City's district heating network

- Electric utility's district heating network.

The units are shut down for about eight hours every 1000 hours for routine inspection and minor maintenance. Every 4000 hours or twice a year, the unit is down for about one week or two for boiler cleaning and major overhaul if needed.

During 1976, the Martin #3 unit was shut down seven (7) times for less than one day for planned 1000 hour routine inspections. In total, the unit was out of service for six (6) weeks.

Zurich used to have an instrument service contract but that became too expensive. Their own people now repair the instruments.

The 4,000 Hour Cycle Between Boiler Cleanings. Readings of key variables on Hagenholz Unit #3 furnace/boiler have been averaged for each of the 26 weeks (4,300 hours) between July 1, 1973, and February 23, 1974 (when the unit was stopped for planned cleaning) and are displayed in Figure J-1.

The following Figure J-2 is similar. It starts February 17, 1977, and goes to June when this visit was made. The unit was not stopped for cleaning. The two figure present results of the plants first half year (1973) and its latest half year of operation (1977 after 30,000 hours). For most of the 1973 period, steam production has hovered around 37.5 tonnes (41.3 tons) per hour. Four years later the figure had decreased to about 35 tonnes (38.5 tons) per hour.

Notice the steady rise in flue gas temperatures during the first 1000 or 2000 hours. The low initial readings reflect excellent heat transfer rates due to rather clean tubes. After the tubes have accumulated deposits, the heat transfer levels out as is indicated by the flat temperature and steam profiles. The superheater and the economizer tubes are stacked (and not staggered). During the first 1000 hours, deposits are beginning to accumulate vertically between close tubes as shown in this diagram by Martin's Heinz Kauffman. Eventually, the space between the close tubes becomes filled with deposits.

TABLE J-9. REPORT OF OPERATIONS 1974 AND 1976

Annual Totals

	1974	1976
Incinerator boiler #1 operating hours (h)	4,766	7,463
Incinerator boiler #2 operating hours (h)	4,561	7,289
Incinerator boiler #3 operating hours (h)	7,004	7,596
Number 2 fuel oil fired 3-pass boiler #1 operating hours (h)	201	182
Waste oil fired 3-pass boiler #2 operating hours (h)	1,486	2,099
Incinerator boiler #1 Steam Generation (tonnes)	112,891	139,930
Incinerator boiler #2 Steam Generation (tonnes)	85,118	125,306
Incinerator boiler #3 Steam Generation (tonnes)	284,255	261,515
Total steam produced from solid waste (tonnes)	482,264	526,751
Steam generation per ton of solid waste, unit #1		
unit #2		
unit #3		
average (t/t)	2.579	2.41
Fossil fuel fired 3-pass boiler #1 - steam generation (tonnes)	1,413	1,404
Fossil fuel fired 3-pass boiler #2 - steam generation (tonnes)	11,244	13,192
3-pass boiler total - steam generation (tonnes)	12,658	14,596
Total steam generation (tonnes)	494,922	541,347
Quantity of solid waste burned (tonnes)	186,968	218,342
Quantity of waste oil burned (tonnes)	794	1,102
Quantity of waste solvents burned (tonnes)	71	113
Quantity of crude oil burned (3-pass boilers) (tonnes)	109	108
Total weight burned (tonnes)	187,942	219,665
Quantity of solid waste collected (tonnes)	186,146	217,503
Quantity of waste oil collected (tonnes)	1,654	1,801
Quantity of waste solvents collected (tonnes)	71	113
Total waste collected (tonnes)	187,871	219,417

TABLE J-9. (Continued)

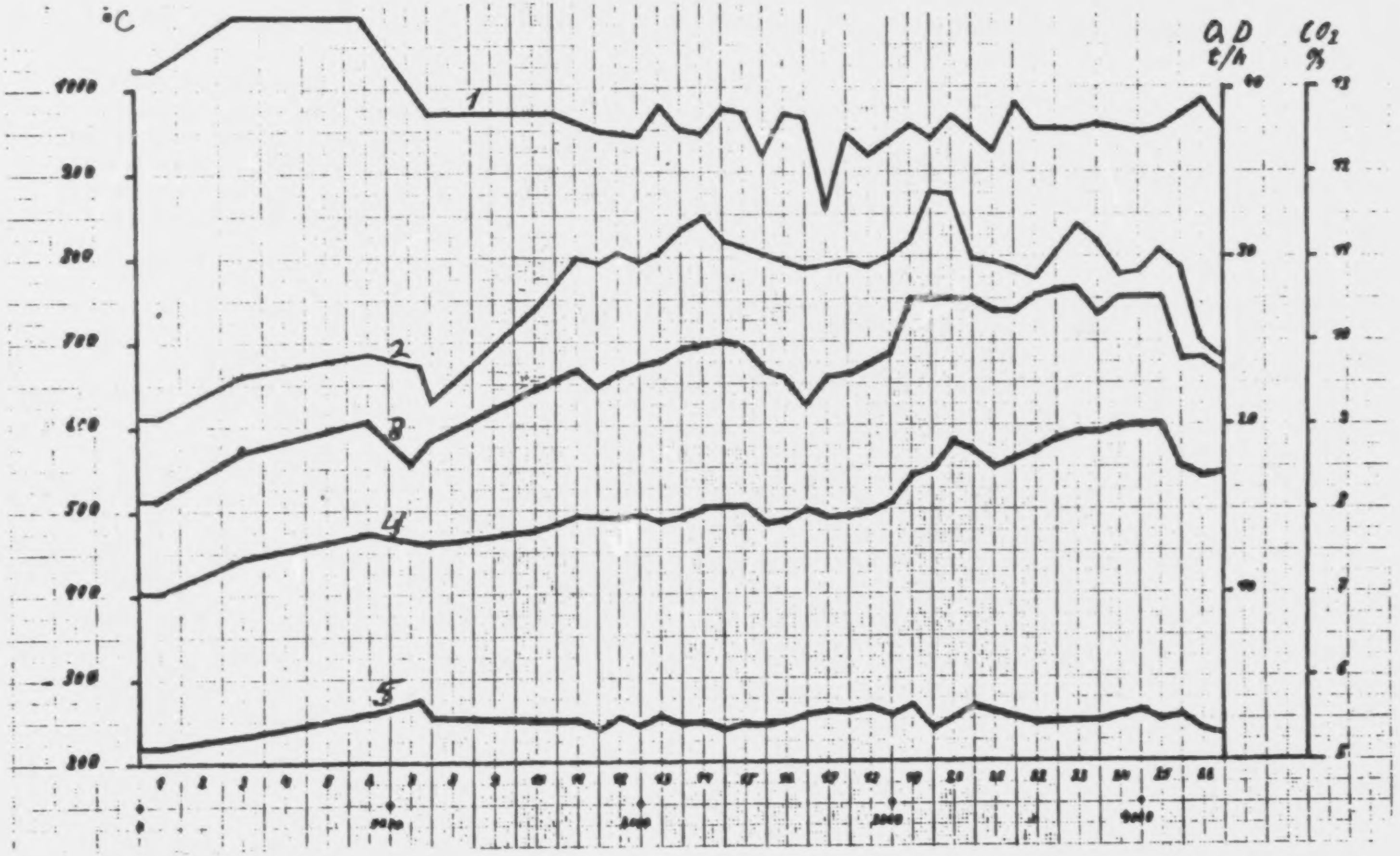
	1974	1976
Make-up for feedwater treatment (Gals.)	6,961,926	6,798,528
Steam turbine #1 operating hours (h)	6,090	6,565
Steam turbine #2 operating hours (h)	5,351	6,160
Steam turbine #1 electric power generated KWH	18,677,670	22,376,817
Steam turbine #2 electric power generated KWH	16,155,350	20,626,620
Total electric current generated KWH	34,697,540	43,003,437
Electric current used for incineration plant KWH	11,540,878	14,276,322
Car and truck repair shop KWH	45,373	47,791
Office building KWH	148,550	131,702
Garage building KWH	39,819	27,406
Flesh-meal plant KWH	24,456	767,760
District heating system KWH	160,668	185,378
Community service KWH	12,740	
Residue processing plant KWH		30,225
Community uses KWH	6,090	
Total consumed for plant system (kWh)	11,973,563	15,466,584
Electric current fed to utility grid (kWh)	23,151,000	28,374,000
Electric current used from utility grid (kWh)	549,700	781,000
Water used for incineration plant kg	197,668,901	125,334,528
Car and truck repair shop kg	829,796	933,240
Office building kg	1,853,945	1,721,016
Garage building kg	114,386	37,488
Flesh meal plant kg	---	8,145,720
Total water consumption kg	200,772,370	136,171,992
Water consumed per ton of solid waste (kg/S. T.)	1,162 *kg/Sh.T 63.3 gals/S. T.	686 37.3

*Normal Water Consumption Per ton of solid waste for Martin System = 20 Gals/Sh.T

TABLE J-9. (Continued)

	1974	1976
Wet Residue* Sh. T	47,594,551	--
Note * not weighed after June 30, 1974		
Heat consumed by car and truck repair shop	1,296 x 10^6 Btu	1.090 x 10^6 Btu
Heat consumed by office building	2,772 x 10^6 Btu	2.895 x 10^6 Btu
Heat consumed by garage building	1,623 x 10^6 Btu	1.623 x 10^6 Btu
Flesh meal plant	---	26,425 x 10^6 Btu
Hot water to local factory	304 x 10^6 Btu	287 x 10^6 Btu
District heating system	---	531,742 x 10^6 Btu
City EWZ (investor-owned public utility)	489,700 x 10^6 Btu	65,687 x 10^6 Btu
Total Heat supplied by hot water and steam	495,695 x 10^6 Btu	629,749 x 10^6 Btu
Operational hours for bulky waste shear	2,931	2,809

(NOTE: The causes of wide fluctuations in system energy consumption were not determined.)



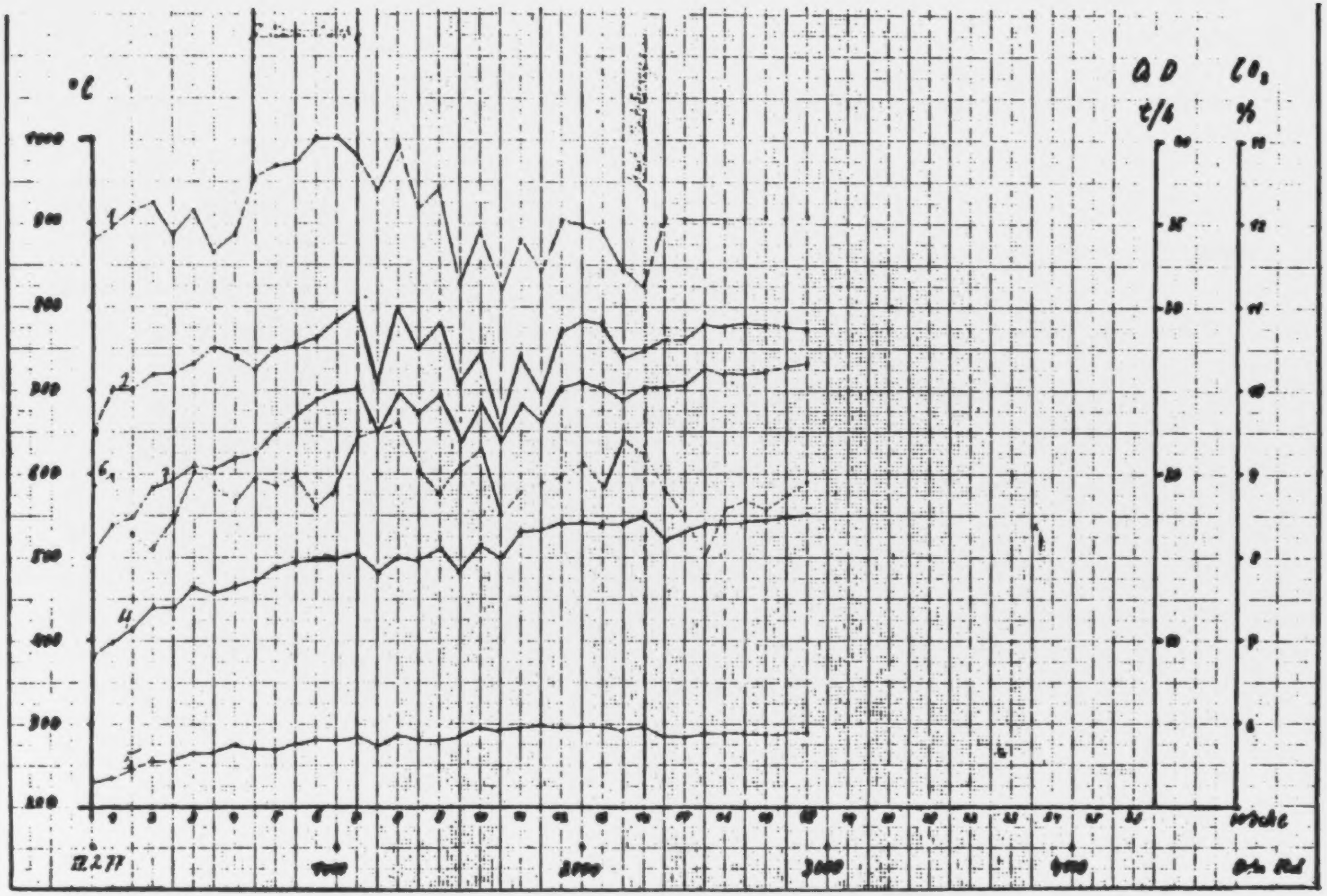
July 1, 1973

February 23, 1974

1 Steam Production (tonnes/hour)
2 Temperature at Top of Furnace First Pass (° C)
3 Temperature Before the Superheater (° C)
4 Temperature Before the Economizer (° C)
5 Temperature After the Economizer (° C)

(First Half Year of Operation)

FIGURE J-1. STEAM PRODUCTION, FLUE GAS TEMPERATURES AND CO_2 LEVELS (WEEKLY AVERAGE) DURING THE 4000 HOUR OPERATING CYCLE BETWEEN CLEANING AT ZURICH: HAGENHOLZ UNIT #3



February 17, 1977 June ?, 1977

1 Steam Production (tonnes/hour)
2 Temperature at Top of Furnace First Pass (° C)
3 Temperature Before the Superheater (° C)
4 Temperature Before the Economizer (° C)
5 Temperature After the Economizer (° C)
6 CO_2 Concentration After the Economizer (° C)

(Last Half Year of Operation)

FIGURE J-2. STEAM PRODUCTION, FLUE GAS TEMPERATURES, AND CO_2 LEVELS (WEEKLY AVERAGE) DURING THE 4000 HOUR OPERATING CYCLE BETWEEN CLEANING AT ZURICH: HAGENHOLZ UNIT #3

After the loss of heat transfer from the initial deposit, the increasing deposit has little effect on further lowering heat transfer and the efficiency remains consistent for the remaining 2000 hours of the cycle.

The economizer is especially large to both recover energy and reduce flue gas temperatures entering the electrostatic precipitators.

In 1973, the flue gas temperature leaving the economizer was around 250 C (482 F) but always below 275 C (527 F) on a weekly average. Four years later, the average temperatures had risen to 290 C (554 F) with occasional excursions to 300 C (572 F), the temperature considered by many to be the temperature above which ESP high temperature corrosion occurs.

Should stack gas temperatures rise 90 C (162 F) above normal, then overall plant efficiency would fall by 5 percent, i.e., not enough energy was absorbed by the boiler tubes from the flue gas stream.

The Hague

In 1976 the plant produced 85,028,300 kw-hr, 71,930,500 kw-hr of which was delevered to the municipal electric system. This earned, at DG 0.03/kw-hr, DG 2,157,915 ($884,391 @ 2.44/$). To achieve this performance the two 11.5 MW steam turbogenerators operated 5710 and 5698 hours respectively, and averaged overall plant availability for generating of 82.9 percent based on a 5.5 day week of operation (6883 hr/yr). As explained earlier, good plant reliability is achieved by having one of the four units available for repair and preventive maintenance.

Of the total energy delivered, 35.7 x 10^6 kw-hr was delivered during the day, 36.2 x 10^6 kw-hr at night. Maximum 5-minute average peak production rate was 19,160 kw at 2:25 p.m. on December 10, 1976.

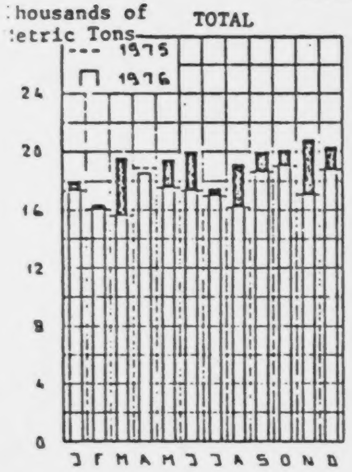
Table J-10 shows an annual summary sheet prepared by the staff each year to depict overall plant performance. In that table the final chart and the final column both have to do with the electrical contract with the parent organization, Gementelijk Energiebrijf (municipal utility). That contract provides a monthly bonus if the waste plant delivers at least 5.5 MW continuously during the 5.5 days of operation each week. The table shows that in 1976 that monthly bonus was won in all months except March, August, and October because on a total of 26 days the minumum rate was not maintained.

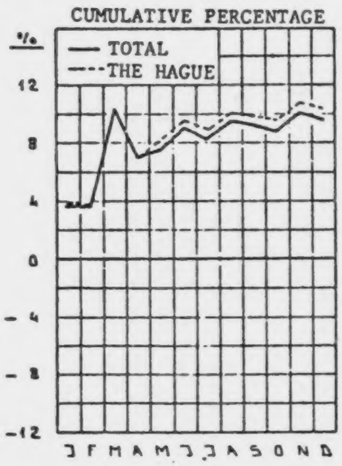
In addition to the annual plant performance tabulation, every month the staff produces a monthly summary of availability of all major plant components showing for each boiler-furnace, turbine, crane, and pump the period of operation, time required for maintenance, repair, or modification. ALso, a hand recorded daily table is included showing, by coded symbols, which days of the month which components did or did not operate and why. Thus, a management can tell at a glance over several months of these coded tables which particular components are trending toward decreasing availability and hence should receive appropriate maintenance.

Table J-11 shows the annual plant performance results for the seven years 1970-1976. The most notable item in this extensive record is steam produced, tonnes per tonne of refuse. Although this plant, as all waste-to-energy plants, must contend with a highly variable source of energy, it shows a remarkably consistent production rate. That rate range for 1.92 to 2.02, a maximum variation over seven years of ± 2.5 percent. The decided drop

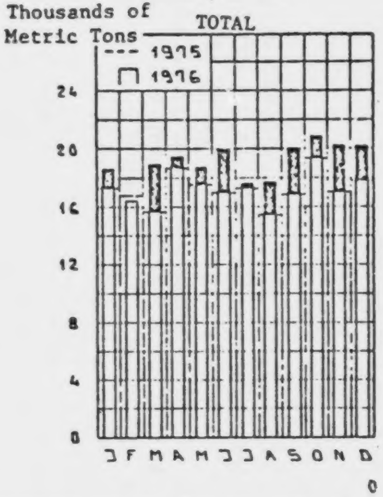
TABLE J-10. REFUSE BURNING SUMMARY, THE HAGUE, 1976 (COMPARED TO 1975)

REFUSE DELIVERED

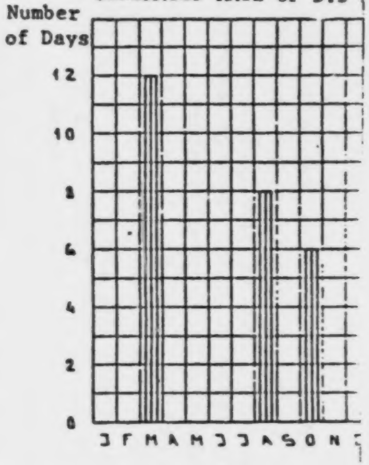




REFUSE BURNED



DAYS PER MONTH WHEN OPERATED BELOW CONTRAC GENERATED RATE OF 5.5



	REFUSE DELIVERED							REFUSE BURNED	
	The Hague		Suburbs		Percent of Annual Deliv.			1975	1976
	1975	1976	1975	1976	The Hague	Suburbs	Total		
	Tonne	Tonne	Tonne	Tonne	%	%	%	TON	TON
JANUARI	15 770	16 379	1 585	1 601	3.9	1.0	3.6	17 285	18 605
FEBRUARI	30 274	31 396	3 012	3074	3.7	2.0	3.6	34 112	35 067
MAART	44 569	49 236	4 479	4 865	10.4	8.6	10.3	49 990	54 088
APRIL	61 772	66 100	6 220	6 580	7.0	5.8	6.9	68 651	73 573
MEI	77 499	83 757	8 033	8 328	8.1	3.7	7.6	86 221	92 390
JUNI	93 099	101 922	9 701	10 111	9.5	4.2	9.0	103 100	112 264
JULI	108 123	117 728	11 460	11 719	8.9	2.3	8.2	120 417	129 916
AUGUSTUS	122 721	135 182	12 996	13 434	10.1	3.4	9.5	135 963	147 650
SEPTEMBER	139 557	153 342	14 686	15 196	9.9	3.5	9.2	154 084	167781
OKTOBER	156 765	171 614	16 468	16 971	9.5	3.1	8.8	173 397	188 590
NOVEMBER	172 259	190 664	18 038	18 745	10.7	3.9	10.0	190 391	208 848
DECEMBER	189 387	209 187	19 877	20 488	10.4	3.1	9.7	208 252	229 099

	ELECTRICAL ENERGY PRODUCED			
	NET POWER DELIVERED		5 Min. Peak Gen.	Days unde <5.5 mw
	Monthly	Cumulative		
	MWh	MWh	MW	Days
JANUARI	5 695	5 695	17.88	–
FEBRUARI	4 812	10 507	16.40	–
MAART	6 241	16 748	17.64	12
APRIL	6 624	23 372	17.60	–
MEI	6 675	30 047	17,64	–
JUNI	6 380	36 427	16.60	–
JULI	5 698	42 125	16.68	–
AUGUSTUS	5 618	47 743	15.36	8
SEPTEMBER	6 004	53 747	15.48	–
OKTOBER	5 298	59 045	13.68	6
NOVEMBER	6 200	65 245	17.88	–
DECEMBER	6 686	71 931	19.16	–

TABLE J-11. THE HAGUE PLANT ANNUAL OPERATING RESULTS OVER SEVEN YEAR PERIOD. (FURNACE 4 BEGAN OPERATION EARLY 1974)

	*	1970	1971	1972	1973	1974	1975	1976
Operating Personnel								
Day Shift Personnel		16	17	18	18	18	20	21
Shift Personnel		33	33	34	34	33	33	33
Total		49	50	52	52	51	53	54
Combustion								
Refuse	t	190,696	197,838	216,787	202,668	206,847	208,100	229,099
Residue								
Clinker	t	70,462	76,781	78,900	72,687	72,694	73,805	83,917
Scrap Metal	t	--	--	--	--	--	--	1,361
Operating Time							4,657	5,687
Per furnace	h						4,385	4,886
							4,819	5,224
							4,972	4,688
Total of all furnaces	h	15,601	16,797	18,817	17,606	16,665	18,833	20,485
Steam								
Steam Production	t	366,257	383,249	432,869	406,489	397,707	419,823	454,152
Steam Production/t Refuse	t	1.92	1.94	1.99	2.01	1.92	2.02	1.98
Steam Delivery	t	--	--	409,176	385,282	375,000	--	--
Power								
Power Consumption x 1000	kWh	9,922	10,356	11,984	11,465	10,860	11,392	13,098
Power Consumpt./t Refuse	kWh/t	52.0	52.4	55.3	56.6	52.50	54.74	57.17
Power Production x 1000	kWh	70,716	71,904	81,835	77,056	69,661	76,803	85,028
Power Production/t Steam	kWh/t	193.08	187.62	189.05	189.58	175.16	182.94	187.22
Power Delivery x 1000	kWh	60,793	61,548	69,852	65,591	58,741	65,411	71,931
Water Consumption								
Total Water Consumption	m^3	1,452,692	1,445,728	1,476,030	1,500,672	1,285,507	1,419,736	1,500,901
City Water	m^3	182,249	178,144	3,650	3,972	3,307	3,616	4,002
Industrial Water	m^3	1,252,250	1,246,360	1,296,700	1,321,500	1,086,000	1,232,700	1,367,485
Water Consumpt./t Refuse	m^3/t	7.62	7.31	6.80	7.40	6.21	6.82	6.55
Well Water	m^3	--	--	175,680	175,200	175,200	162,000	--

*Metric Units.

in rate in 1974 is attributed to the severe energy crisis caused by the Arab oil embargo beginning in October 1973. Plant staff surmised thaat many householders found ways to reduce the amount of combustible materials discarded.

Dieppe

The operating group, Thermical-INOR, is required by its contract with the city of Dieppe to gather and submit performance data for the refuse and wastewater plants. Tables J-12 and J-13 show the refuse plant results for the year 1976. The total two-furnace operating time of 6,228 hours is 35 percent based on a total of two times 8,760 hours/year. Based on a 5-1/2 day week, the operation time is 45 percent. As indicated early in this report, the Dieppe plant was sized in anticipation of considerable growth in load.

Table J-14 summarizes the refuse plant operation over the 5 years, 1972-1976. Load and performance have been quite steady over that period.

Gothenburg: Savenas

The system is achieving its goals of useful energy recovery while disposing of the industrial and community solid wastes from 670,000 inhabitants in nine communities. Various equipment problems have been encountered as already described and as solutions have been found, overall performance is improving. Final costs per unit of waste handled have increased due to inflation and equipment modification.

Table J-15 summarizes the plant input and output in 1976.

The total length of time that each unit operated for the year corresponds to the following availabilities on 7-day week plant operation:

Unit 1	76 percent
Unit 2	84 percent
Unit 3	72 percent

These are typical availabilities for this type of plant.

The heat utilized--235,869 Gcal--amounts to 0.9725 Gcal/tonne of refuse (3.508 M Btu/ton). Assuming the current estimated average heat value of 2,350 Kcal/kg, this represents a final annual use of 41.4 percent of the potenially available energy in the refuse. Assuming a boiler-furnace efficiency of 70 percent, this corresponds to an effective use of 59 percent of the energy generated as steam. A significant block of the energy liberated must be dissipated in the air-cooled condensers in the 4 months May through August because little district heating is needed then.

Table J-16 summarizes the plant performance for the 3 years, 1974-1976. The major changes to the water-tube walls and secondary air system in 1975 caused a loss of operation, particularly with Unit 2. All of the units increased operation in 1976, particularly Unit 2, whichh is a hopeful sign that many of the early problems have been solved.

Uppsala

Table J-17 shows the 1974 and 1975 operating results for the entire Uppsala district heating and power system. In 1975, the waste burning plant produced 80 Gwh (243 x 10^6 MBtu) in the form of saturated steam at 15 atm (220 psi). This was 5.4 percent of the totla heat production in the entire system.

TABLE J-12. SUMMARY FOR 1976 OF REFUSE-SLUDGE BURNING PLANT OPERATION AT DIEPPE. TABULATION PREPARED BY PLANT OPERATORS, THERMICAL-INOR, IN FULFILLMENT OF THEIR OPERATING CONTRACT WITH THE CITY

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Source and Amount of Refuse, kg													
Dieppe	826,350	751,250	879,950	873,300	893,000	889,950	943,800	914,350	839,200	864,100	855,150	826,650	10,357,050
Neuville les Dieppe	331,700	304,300	365,500	354,100	359,050	351,150	339,550	327,750	353,350	357,400	375,500	352,650	4,172,000
Rouxmesnil	21,400	17,850	22,850	25,950	24,100	20,400	24,450	21,250	22,500	25,850	26,300	25,550	278,450
Manehouville	1,200	1,300	1,400	800	1,100	2,150	1,200	1,600	1,400	1,200	1,150	1,850	16,350
Martigny	2,600	3,050	2,600	2,700	3,000	2,700	2,250	3,350	3,100	3,150	3,000	2,550	34,050
Crosville	1,100	1,400	900	1,200	1,050	1,100	1,250	2,050	1,500	900	1,450	900	14,800
La Chaussee	750	1,200	1,100	950	1,150	900	950	1,400	1,150	1,500	1,200	1,000	13,250
La Chapelle du Bourgay	400	500	500	550	700	400	450	700	650	500	550	500	6,400
Industrial, Commercial	156,700	149,750	144,700	123,800	123,300	134,400	125,850	62,350	127,250	112,800	116,850	158,600	1,536,350
TOTAL REFUSE, kg	1,342,200	1,230,600	1,419,500	1,383,350	1,406,450	1,403,150	1,439,750	1,334,800	1,350,100	1,367,400	1,381,150	1,370,250	16,428,700
Volume of Digested Sludge Dried and Burned, m^3	315	405	345	395	390	345	345	460	415	490	350	345	4,600
Production of Clinker, kg	646,050	568,550	612,350	550,350	488,650	677,500	608,350	582,600	568,050	594,050	636,100	617,550	7,149,750
Electrical Energy Consumed, kw	62,700	54,700	54,600	58,700	55,300	76,000	73,200	60,200	55,200	61,000	59,400	65,900	736,900
Period of Furnace Operation													
Furnace 1, hours	191	209	376	271	0	300	293	163	310	319	344	173	2,949
Furnace 2, hours	295	229	112	176	443	402	305	351	160	227	211	368	3,279
Total Furnace Operation	486	438	488	447	443	702	598	514	470	546	555	541	6,228

TABLE J-13. DIEPPE WASTEWATER PLANT SUMMARY FOR 1976. TABULATION PREPARED BY THERMICAL-INOR, IN FULFILLMENT OF THEIR OPERATING CONTRACT WITH THE CITY

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Wastewater treated, m^3	133,630	136,750	148,480	139,320	153,260	152,350	150,960	132,420	162,550	139,290	132,280	158,900	1,740,190
Digested sludge produced, m^3 (approx. 92% water)	315	405	345	395	390	345	345	460	415	490	350	345	4,600
Gas produced, m^3 (approx. 65% CH_4)	11,737	13,925	15,967	14,810	14,535	14,391	12,366	11,040	13,362	12,916	11,381	11,518	157,948
Chlorine used, kg	75	75	75	75	75	75	75	75	75	75	75	75	900
Electricity consumed, kWh	44,700	42,100	45,700	44,300	42,600	41,500	41,800	38,700	42.400	44,800	43,500	45,900	518,000

TABLE J-14. ANNUAL REFUSE INCINERATOR OPERATING RESULTS FOR DIEPPE - 1972-1976 (COURTESY VON ROLL, LTD.)

		1972	1973	1974	1975	1976
Combustion						
Refuse	tonnes	17,291	18,885	19,185	18,446	16,428
Clinker and flyash	tonnes	6,702	7,265	7,359	7,298	7,149
Operating Hours						
Furnace 1	h	3,423	3,281	4,083	3,325	2,949
Furnace 2	h	3,985	3,353	4,343	3,153	3,279
Power Consumption x 1000	kWh	733	779	818	711	737
Power Consumption/t Refuse	kWh/t	42.42	41.25	42.62	38.54	44.85
Total Water Consumption	m^3	941,538	1,079,968	910,061	827,396	--
City Water	m^3	43,298	68,578	51,441	53,246	--
Industrial Water	m^3	898,240	1,011,390	858,620	774,150	--
Water Consumption/t Refuse	m^3/t	54.45	57.19	47.44	44.86	--

Note: To convert metric tonnes to short tons multiply by 1.1
To convert cubic meters to gallons multiply by 264.2

TABLE J-15. 1976 OPERATING RESULTS FOR GOTHENBURG: SAVENAS PLANT (Courtesy of Graab)

	Refuse Burned Tonnes				Time of Operation Hours			Steam Production Tonnes				Treated Boiler Feedwater m^3	Total Feedwater m^3	Industrial Water Used m^3	Energy Recovered Gcal	Power Consumpt kWh x 1
	Unit 1	Unit 2	Unit 3	Total	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Total					
January	8,639	7,694	2,451	18,784	698	627	231	29,908	23,709	7,827	61,444	2,063	4,981	11,093	23,259	1,112
February	3,489	7,534	8,116	19,139	340	696	693	12,159	22,264	25,832	60,255	2,052	3,973	13,641	23,876	1,065
March	6,698	7,234	8,748	22,680	564	678	740	22,365	21,784	28,419	72,568	2,365	5,228	13,406	27,619	1,226
April	8,280	5,967	6,832	21,079	718	467	642	27,429	18,194	23,450	69,073	2,214	4,665	15,104	22,143	1,140
May	4,300	9,236	8,374	21,910	342	713	689	13,900	27,852	27,690	69,442	2,354	4,583	13,915	15,313	1,176
June	8,294	8,081	1,847	18,222	692	708	200	27,003	24,699	5,798	57,500	2,388	5,352	15,089	10,860	1,033
July	3,117	7,848	7,422	18,387	252	639	636	10,180	24,308	22,872	57,360	2,354	10,304	11,451	8,834	1,067
August	7,268	6,328	3,859	17,455	723	634	430	23,974	19,991	12,347	56,312	2,448	5,367	15,500	14,006	1,029
September	3,763	9,487	8,334	21,584	322	719	704	12,684	29,709	26,882	69,275	2,251	4,536	14,367	19,145	1,118
October	8,172	9,608	2,212	19,992	725	744	193	27,494	29,003	6,792	63,289	1,808	3,429	11,334	19,578	1,057
November	7,496	6,983	6,121	20,600	667	624	487	24,034	20,298	18,471	62,803	2,619	6,910	9,150	22,711	1,095
December	7,331	6,818	8,555	22,704	643	511	706	24,009	21,722	26,943	72,674	2,403	4,823	14,741	28,525	1,178
Total	76,847	92,818	72,871	242,536	6,686	7,360	6,351	255,139	283,533	233,323	771,995	27,319	64,151	158,791	235,869	13,296

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TABLE J-16. GOTHENBURG SÄVENÄS ANNUAL RESULTS 1974-1976

Furnace start-up: 1972 Capacity: t/24 h 3 x 300		1974	1975	1976
Operating Personnel				
Day Personnel		22	28	
Shift Personnel		20	20	
Total		42	48	
Refuse Fired	tonne	214,885	187,319 (1)	242,536
Residue	tonne	66,133	56,165	
Operating Hours				
Furnace 1	h	6,242	5,484 (2)	6,686
Furnace 2	h	5,700	4,751	7,360
Furnace 3	h	5,852	6,035	6,351
Total		17,794	16,270	20,397
Availability	percent	67	62	77
Steam Production	tonne	663,906	586,668	771,995
Steam Production/t Refuse	tonne	3.09	3.13	3.18
Heat Supply	Gcal	178,922	184,068	235,869
Power Consumption x 1000	kWh	10,248	10,537	13,296
Power Consumption/t Refuse	kWh/t	47.69	56.25	54.82
Water Consumption				
Total Water Consumption	m3	217,660	173,963	186,110
Industrial Water	m3	185,091	141,698	158,791
Water Consumption/t Refuse	m3/t	1.01	0.93	0.77
Boiler Feed Water	m3	32,569	32,265	27,319

(1) Total stop about 15 days.

(2) Boiler revision and repair.

TABLE J-17. OPERATING DATA FOR THE UPPSALA ENERGY SYSTEM FOR 1974 AND 1975 (COURTESY UPPSALA KRAFT-VARME AB)

	1974	1975
Electricity Production, Gwh	313	520
Hot Water From Power Plant, Gwh	655	1,020
Hot Water From Three Heating Plants(a), Gwh	463	206
Hot Water From Central Heating Plant, Gwh	24	34
Steam Production From Waste, Gwh	80	81
Steam Production From Others(b), Gwh	41	32
Heat From Heat Exchanger, Gwh	38	30
Total Production (Hot Water + Steam), Gwh	1,263	1,373
Delivery of Hot Water From Four Plants, Gwh	1,017	1,166
Delivery of Hot Water From Central Plant, Gwh	22	31
Delivery of Steam (Pharmacia, Farmek, KVV), Gwh	56	59
Oil Consumed:		
Power Plant (for Power), m^3	36,943	62,834
Power Plant (for Hot Water), m^3	63,303	99,930
Three Heating Plants for Hot Water(a), m^3	44,580	21,453
Central Heating Plant, m^3	2,987	4,034
Bolandsverket Plant for Steam, m^3	4,128	3,296
Total Oil Burned, m^3	115,643	129,051
Specific Oil Consumption (Three Plants + Power Plant), Mwh/m^3	9.3	9.6
Specific Oil Consumption, Central Plant, Mwh/m^3	7.4	7.7
Oil From Coastal Terminal to Storage, m^3	173,179	188,182
Waste Burned, tonne	50,878	51,355
Waste Plant Evaporation Rate, kg/kg	2.44	2.44

TABLE J-17. (Continued)

	1974	1975
Length of District Heating System, m	164,201	189,656
Volume of Hot Water Circulated, m^3	13,486	15,386
Income		
From Hot-Water Customers, 1,000 Skr	63,355	73,801
From Steam Customers, 1,000 Skr	2,588	2,898
From Delivery of Refuse, 1,000 Skr	1,888	1,693
Rate of Income From Heat Customers, ore/kwh (c)	6.10	6.17
Tipping Fee, Skr/tonne	37.11	33.62

(a) The three heating plants are: Bolandsverket, Kvarngardesverket, and Husbyborgs Verket

(b) Other small steam sources are Sunrod and Kymmene.

(c) 1 skr = 20 ore.

The waste burning plant achieved its energy recovery and waste disposal function with minimal cost.

Figure J-3 shows the component arrangement of the Uppsala plant. The original three furnaces installed in 1960 are manifolded to feed hot gas to either of two steam boilers. The fourth furnace, installed in 1970, serves a third, larger boiler. The nominal capacities of the components are as follows:

	tonnes/hr	tons/hr	tons/day
Furnace 1	3.0	3.3	79
Furance 2	3.0	3.3	79
Furnace 3	3.5	3.9	94
Furance 4	5.0	5.5	132
TOTAL REFUSE CAPACITY 384		14.5	16.0
Boiler 1	10.0	11.0	--
Boiler 2	15.0	16.5	--
Boiler 3	15.0	16.5	--
TOTAL STEAM CAPACITY	40.0	44.0	88,000 lb/hr

However, these total capcities are only ratings as the plant was not intended to and never operates all components at full capacity. Usually some components are down for service. The actual average plant burning rate for 1976, 51,000 t/d was the equivalnt of an average rate of about 200 tons/day based on a 5-day week. This is 52 percent of rated capacity.

Horsens

Early problems resulting from higher than expected heat value of the refuse have been solved by some refractory revisions plus judicious furnace operation to avoid firing too much industrial refuse. In the 4 years of operation, only two truck loads of refuse have had to be sent to the landfill because the plant was down, except for the period in 1977 while the spray cooling chamber was being replaced by the waste heat boiler. This is especially notable when one considers that there is only one line, i.e., no redundancy.

Copenhagen: Amager

The monthly operating hours for the three-line total are shown in Figure J-4. At the recent average of 1,700 hours per month, the plant operated about 80 percent of the of the time.

During the 1975-76 fical year (April 1 to March 31), the three furnaces together operated 19,663 hours or 75 percent of time available. This equates to an average of 13 tonnnes (14.3 tons) per hourper furnace. This compares with a design capacity of 12 tonnes (13.2 tons) per hour per furnace. This higher refuse flow rate is consistent with the previous discussion on

Manoverrum '- Control
Room
UGN.2 - Furnace 2
UGN.3 - Furnace 3
UGN.4 - Furnace 4
(UGN.1 is connected by
a duct to steam
boiler AP 1)
AP 1 - Boiler 1
AP 2 - Boiler 2
AP 3 - Boiler 3
7 & 8 Electrostatic
Precipitators

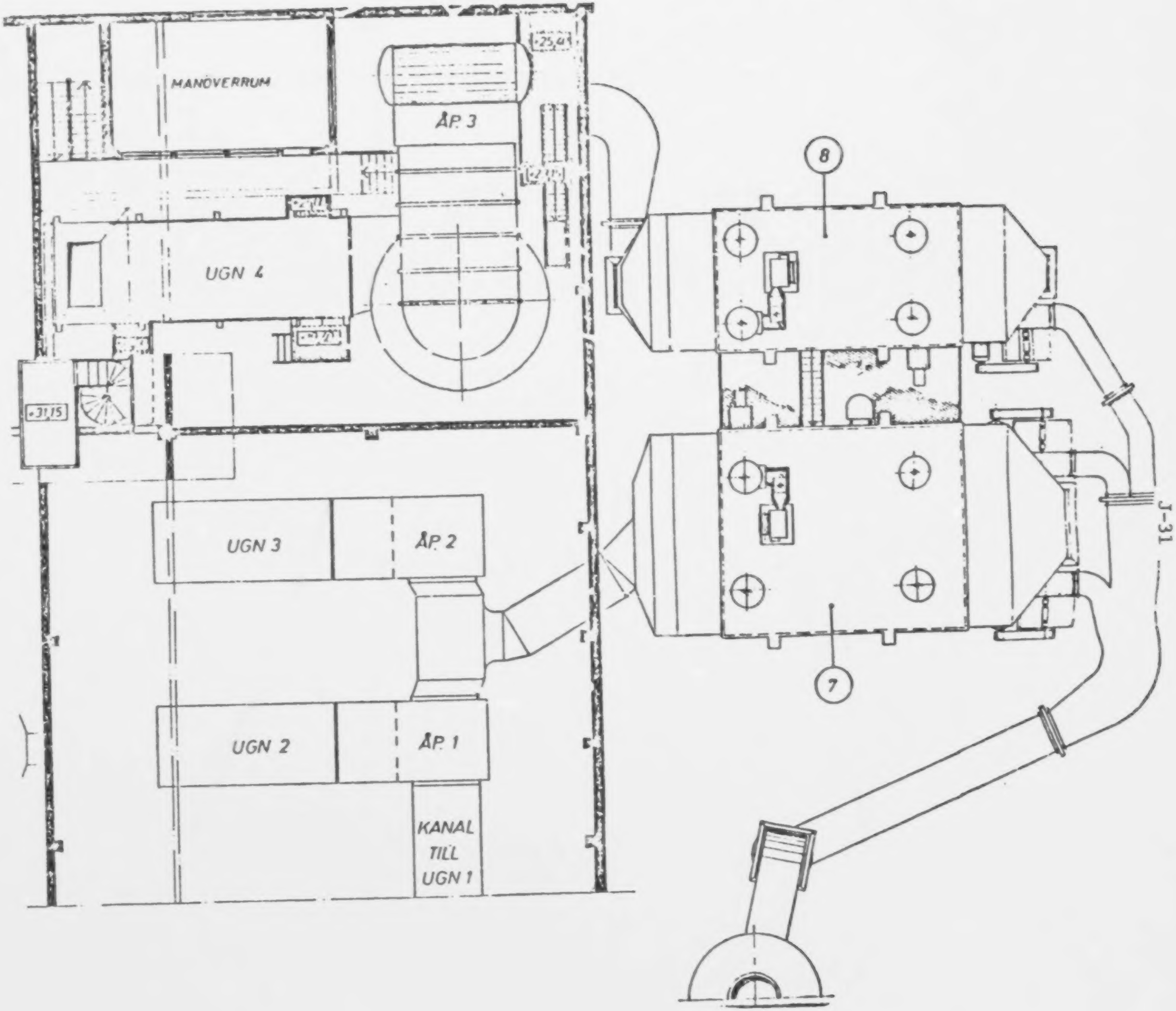
MANÖVERRUM
ÅP. 3
+25,41
8
UGN 4
+31,15
UGN 3
ÅP. 2
UGN 2
ÅP. 1
KANAL
TILL
UGN 1
7

FIGURE J-3. ARRANGEMENT OF COMPONENTS OF BOLANDERNA INCINERATOR PLANT (COURTESY OF UPPSALA KRAFTVARME AB)

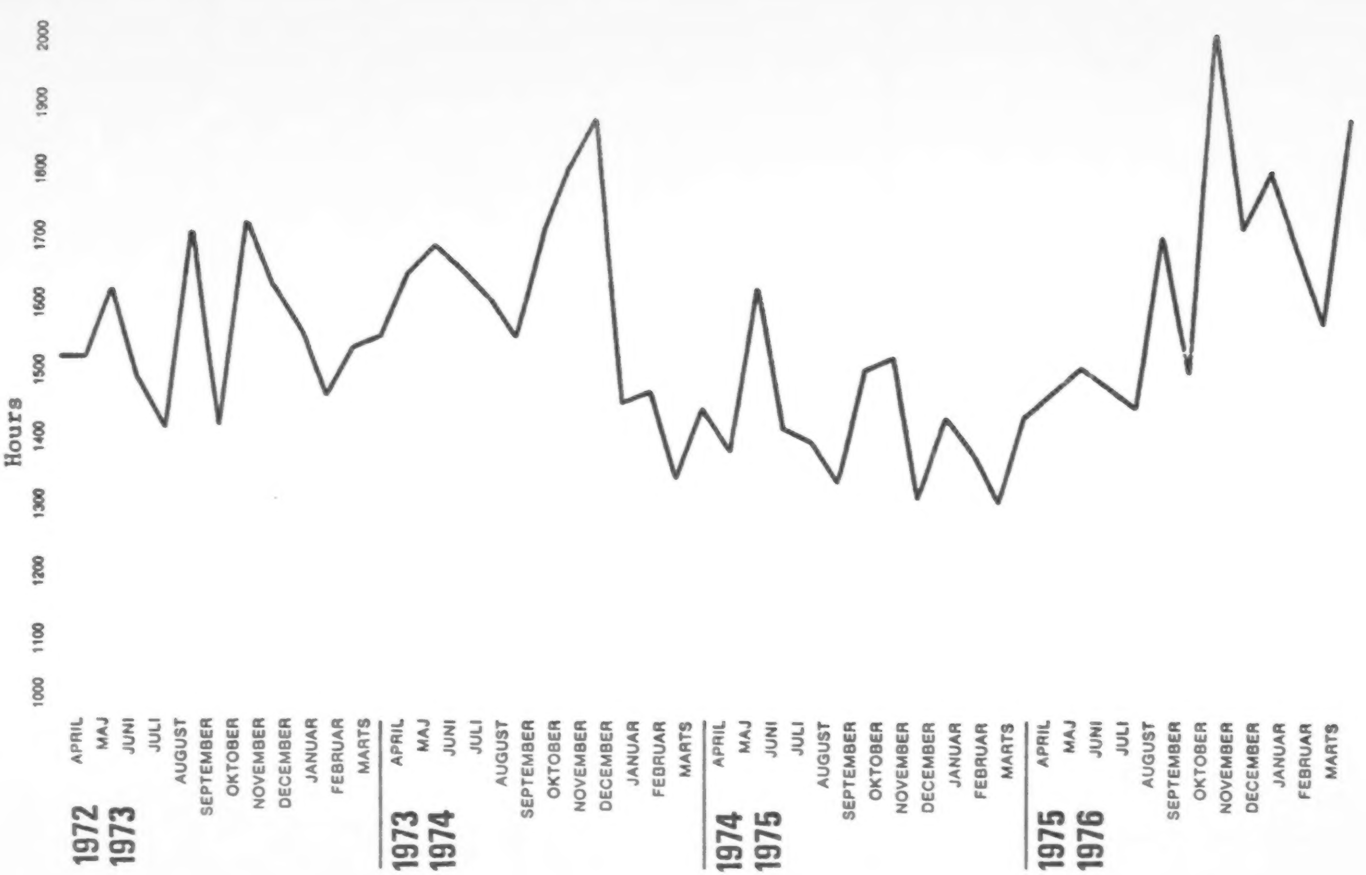

FIGURE J-4. TOTAL (THREE LINES) OPERATION HOURS PER MONTH maximum rated capacity. Because the average calorific value is 1,800 kcal/kg, then more refuse can be processed.

Plant officials have identified three old and partially solved problems as well as five continuing concerns.

Old Problems

- The crane was under capacity
- The grate-furnace refractory grossly failed due to poor anchoring
- The ash handling conveyor system had excessive wear due to fines buildup.

Continuing Concerns

- The rotary kiln must occasionally be repaired
- The convection section has temperature corrosion due to low temperature boiler feedwater
- The economizer must be manually cleaned every 1,500 to 2,000 hours, thus, setting the maintenance schedule
- The electrostatic precipitator corrodes slightly due to running "hot" when the economizer is clogged and is not properly cooling the flue gases
- The ash handling system, while improved, is still causing problems due to "fines".

Copenhagen: West

Battelle's host for the Volund visit was Gabriel S. Pinto. In April, 1976, he wrote an excellent article in an internal Volund publication* that discusses basic design of the total operating system. The following summarizes the article and Figure J-5.

For purposes of the vendor's guarantee to the customer, there must be a clear understanding of the relation between Maximum Rated Capacity (MRC) and the Net Calorific Value (NCV). The numbers used in the example figure are those associated with the Volund rotary Kiln Furnaces.

For each furnace designed by Volund, a theoretical diagram, similar to Figure J-5, is developed. Its purpose is to show how the MRC (tonnes/hr) is a function of net calorific value (kcal/kg).

As an example, assume that the NCV is 2,000 kcal/kg. Typically, such MRC waste has the following composition:

Inerts	25 percent
Moisture	30 percent
Combustibles	
Carbon	8.6 percent
Cellulose	34.8 percent
Plastics	1.6 percent
Total Cumbustibles	45 percent
	100 percent

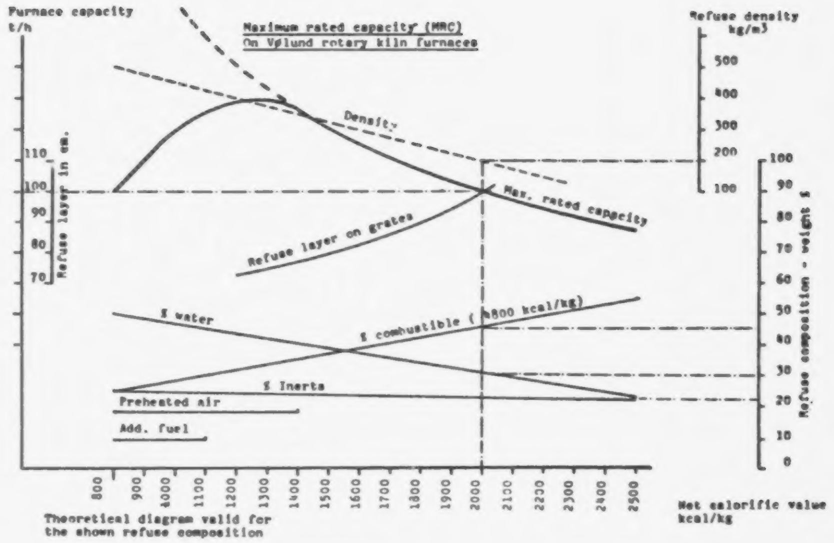

FIGURE J-5. TAKEN FROM AN ARTICLE WRITTEN BY GABRIEL S. PINTO IN APRIL, 1976 THAT DISCUSSES BASIC DESIGN OF THE TOTAL OPERATING SYSTEM AT COPENHAGEN:WEST*

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*An internal Volund Publication

The refuse feeder is to be adjusted so that the refuse layer on the grate is 1 m (3 ft). This type of refuse, at the named layer thickness, has an average density of 200 kg/m^3 (450 pounds/yd^3.

More must be known about the specific system before the MRC answer (in tonnes/hour) can be given. The effective grate area must be known. The following formula relates key variables:

$$\frac{\text{MRC (tonnes)}}{\text{hour}} = \frac{\text{Effective Grate Area (m2)} \cdot \text{Grate Load } \frac{\text{kcal}}{(\text{m}^2\ \text{hour})}}{\text{Net Calorific Vlaue } \frac{\text{kcal}}{(\text{kg})} \cdot \frac{1000\ \text{kg}}{(\text{tonne})}}$$

At this point, some rules of thumb need to be stated:

- For hotter refuse with NCV of 1800 to 2500 kcal/kg, grate load ranges from 600,000 to 650,000 kcal/m^2 · hour.
- For cooler refuse with NCV under 1800 kcal/kg, the grate load ranges from 450,000 to 550,000 kcal/m^2 · hour.

Experience of Volund must be used to actually estimate the grate load. But once estimated, the capacity can be determined. Mr. Pinto's example does not refer to any one system so we have arbitrarily added capacity figures of 5.5 to 8.5 tonnes per hour.

An important design consideration can be seen from the capacity versus NCV curve. It is uni-model peaking at 1200 - 1400 kcal/kg. As an example, it is assumed that the plant is nominally designed to burn 7.0 tonnes per hour of refuse assuming it to have a 2000 NCV.

Perhaps on a Spring day, rain is excessive. The moisture percent rises from it normal 30 percent to 37 percent; the combustibles fall from 45 percent to 38 percent; the density increases from 200 kg/m^3 to 300 kg/m^3 and inerts remain constant. The air preheater remains unchanged and the use of any other fuel remains unchanged.

With the conditions of the wet waste given, the operator may increase the feed rate, raise the feed layer thickness of 120 cm (3.94 ft) and thus increase the throughput from its nominal 7 tonnes per hour up to 8 tonnes per hour.

This of course has a logical limit. If the refuse becomes too wet, full of inerts, and lacking in NCV, then less tonnes per hour can be processed. The furnace could easily choke on even 5 tonnes per hour of soggy rags and house furnace ashes if autothermic reactions are not possible.

In the other direction, above a NCV of 2000, this particular furnace should process slightly less refuse per hour.

Mr. E. Blach, Volund's former chief engineer, wrote in 1969 an excellent paper outlining Volund's product offerings and its philosophy. The following section presents some of the philosophy of how plants should be operated. Several of his other sections appear later.

Forms of Operation

> "The best way of running an incinerator plant is running it 24 hours a day, i.e. continuous operation. The big variations of temperature at start and shut-down cause more wear in a furnace and the auxiliary machinery than a steady operation, and corrosion and cleaning

problems, etc. in the boiler part also decrease by contiqual operation. With regard to possibilities of maintenance and repair, continual operation is not possible for a 1-furnace plant, and that is one of the reasons why an incinerator plant should usually consist of at least 2 furnace units. Unfortunately, this is often not economically possible at the small plants."

"An ideal way of operation for plants with several furnaces is obtained by always keeping a spare oven, while the othher or the othhers run continuously. Through a convenient rotation so that the furnaces alternately are taken out of operation there is plenty of time for inspection, maintenance and repair of each furnace. Small damages can thus be found and repaired before they spread and require big and expensive repairs. At one-furnace plant, the possibilities of inspection are smallere and it can be tempting to let a long time pass between maintenance and repair stops so that the damages grow big and expensive to repair."

"With non-continuous operation, which in practice is 1 or 2 shifts operation, the furnace is stopped, when the operation is discontinued, e.g. the furnace is fed with suitable amount of refuse proportionally to the stand-still period, after which the grate movement and combustion air as well as I.D. fan are stopped. The natural draught will then keep a slow combustion, which develop sufficient heat to keep the plant warm all through so that it can quickly get up to full capacity, when it is started again. After a couple of hours the temperature of the flue gases will be so low, however, that there is the risk of condensation, and thus, corrosion in the convection part of the boiler, althoughh the boiler water still can be kept at full temperature, and the boiler shunt can ensure min. 70 C return flow temperature. Therefore, at stops of more than 6-8 hours there must be taken special measures, such as by-pass with damper around the boiler and its convection part. This is rather difficult construction to carry out in sufficiently strong and practical form because of the high temperatures."

"Furthermore, it results in the operational inconvenience that changing over cannot take place till the flue gas temperature is below 400 degree C, which normally means after 3-4 hours' stop."

"During week-end stoppages the temperature of the boiler water cannot be maintained, and it will in this case be necessary also to keep the boiler warm by circulation of hot water."

ENERGY UTILIZATION

General Comments

Each European resource recovery plant has a complicated and often unique energy use pattern. It was therefore necessary to categorize information into first, second and third step energy forms and uses as shown in Table K-1.

In the first step, the energy in flue gas can be used to dry sewage sludge directly or to produce hot water or steam in a boiler. There is a geographic split with steam being produced in central and southern Europe, while hot water is often produced in Scandinavia. Central Europeans claim that steam is more useful while the Scandinavians make calculations to show that hot water is more efficient.

We have wondered whether the geographic difference is an accident of industrial location. The four steam related water-tube wall vendors (Von Roll, Widmer & Ernest, Martin and VKW) happen to be located in Central Europe. Both Volund and Bruun and Sorensen, the continent's leading refractory wall furnace hot water generator vendors are in Denmark. The water-tube wall furnace/boilers can economically produce high temperature steam. Producing hot water in such a water tube wall furnace might be considered a waste of capital investment money. The refractory wall furnaces are generally less expensive and would have technical difficulties raising steam temperature to much above 315C (600F).

So the question arises, "Do the Danes purchase refuse fired hot water systems (1) because Volund and Bruun & Sorensen are there locally and that is what they sell or (2) because hot water systems are more efficient and relevant to northern climates. These researchers do not have a clear answer at this time.

As a summary to the previous table, Table K-2 was prepared showing how often key functions are included in the design.

Several years ago Klaus Feindler prepared a table showing heat utilization from 28 German refuse energy plants started up during the 1960-1975 period. (See Table K-3). While not obvious from this, there is a trend away from plants producing only electricity to co-generation plants producing electricity and district heating hot water.

Many of the foregoing comments refer to salable energy uses. Internal uses and losses also need to be considered by the designer. There are some internal uses necessary while there are some internal losses that need to be minimized as shown in Table K-4.

TABLE K-1. THREE STEPS OF ENERGY FORM AND USE AT VISITED EUROPEAN PLANTS

	Werdenberg-Liechtenstein	Baden-Brugg	Duesseldorf	Wuppertal	Krefeld	Paris: Issy	Hamburg: Stellinger-Moor	Zurich: Hagenholz	The Hague	Dieppe (And Deaville)	Gothenburg	Uppsala	Horsens	Copenhagen: Amager	Copenhagen: West	TOTAL
First Step	**Energy Form And Use**															
Flue Gas to Dry Sewage Sludge					x								x			2
Flue Gas to Heat Hot Water in Boiler													x	x	x	3
Flue Gas to Heat Steam in Boiler	x	x	x	x	x	x	x	x	x	x	x	x				12
Intake of Exhaust Air from Other Process for Distruction					x			x			x	x[2]	x			5
Second Step	**Energy Form And Use**															
Hot Water for Specific Industrial Uses																0
Hot Water for Internal Uses													x	x	x	3
Hot Water to the Wastewater Treatment Plant		x														1
Hot Water for District Heating (Direct)													x	x	x	3
Steam for District Heating (Direct)						x		x								2
Steam for Specify Industrial Uses	x				x			x				x				4
Steam for Internal Uses	x	x	x	x	x	x	x	x	x		x	x				11
Steam to Make Hot Water	x		x					x			x	x				5
Steam to Make Electricity	x	x	x	x	x	x		x	x							8
Steam Dry Sewage Sludge										x						1
Third Step	**Energy Form And Use**															
Hot Water for District Heating (Indirectly From Steam)	x		x					x			x	x				5
Electricity for Specific Industrial Uses		x														1
Electricity for Internal Uses	x			x	x			x								4
Electricity for the Network	x	x	x	x[1]		x	x	x	x							8
Electricity for the Wastewater Treatment Plant		x			x											2
Large Quantities of Steam Wasted on Roof	x			x			x				x					4

[1] Only if extra electricity remains after Internal Uses.

[2] Exhaust air from the pathological and dextrose incinerators is sent to the refuse furnace/boiler system for destruction, i.e., a partial energy use of the system is as an afterburner.

TABLE K-2. KEY ENERGY FUNCTIONS OF 15 VISITED SYSTEMS

	Number of Systems Having The Energy Use Category	Percent
• Sludge Destruction	3	20
• District Heating	9	60
• Electricity Export to the Network	8	53
• Industrial Process Steam	5	33
• Destruction of Exhaust Gases From Other Processes	5	33
• Systems Wasting Large Quantities Of Steam in Condensers	4	27
• Internal Use of Energy Produced	14	93

OUT OF A SAMPLE OF 15 PLANTS

TABLE K-3. HEAT UTILIZATION FROM GERMAN REFUSE POWER PLANTS START-UP DURING THE 1960-1975 PERIOD

PLANTS		ANNUAL THROUGHPUT		
NUMBER	MARKET FRACTION IN %	REPORTED IN MTPY	MARKET FRACTION IN %	TYPE OF HEAT UTILIZATION
10	35.7	2,272,000	50.6	Integrated into electrical power plants, or operated in combination with electrical power plants, and/or electrical power generation for in-plant use.
10	35.7	1,332,500	29.6	Combination of electrical power generation, (except for in-plant) with district heat distribution.
6	21.4	520,000	11.6	Heat generation for district heating only.
1	3.5	355,000	7.8	Combination of electrical power generation with district heating and sludge disposal.
1	3.5	5,500	1.2	Sludge treatment only.
Σ 28	Σ 99.8	Σ 4,485,000	Σ 100.8	

TABLE K. INTERNAL USES AND LOSSES OF REFUSE DERIVED ENERGY

Uses

- Preheat incoming combustion air
- Reheat outgoing combustion air after scrubbing
- Preheat boiler feedwater
- Heat the plant interior space
- Electrify many parts of the plant
- Dry sewage sludge internally before combustion
- Blow steam through sootblower

Losses

- Cooling steam in condensers
- Escapes in stack
- Escapes in pressure relief valve
- Escapes in ash and quench water
- Escapes in sampling for air quality

District Heating (D.H.)

District heating commercialization varies extensively by country as shown in Figure K-1. The United States figure is not shown because data is not kept by the IDHA in a similar manner. The world's largest D.H. country is the U.S.S.R. Frankly, D.H. commercialization is faster with more centralized planning and control where there is less pressure on immediate economic returns. In Western Europe, West German systems deliver the most energy. Scandinavia, however, has the highest per capita rate.

Interestingly, the world's first district heating system was on Chestnut St. in Lockport, New York in 1877. Its inventor, Birdsill Holly is considered by most to be the father of district heating. Later, in 1909 after several systems had been built, several system developers met at the Southern Hotel in Columbus, Ohio (5 miles from the world headquarters of Battelle Memorial Institute). Attendees formed the National District Heating Association which was later to become the International District Heating Association now located in Pittsburg, Pennsylvania.

The American systems were mostly steam. In recent years many European D.H. systems use only hot water. Several European met on the tour suggested the lackluster D.H. situation in America of the last 20 years was partially the fault of using steam and not hot water. "Energy losses are greater with steam, maintenance is higher and steam can only be transported 1/3 the distance as hot water" would be a typical European assessment.

These researchers are not sure if the above is the complete story. As the U.S. EPA and State agencies improve the atmospheric environment, there has been pressure on existing D.H. systems to spend larege sums for pollution

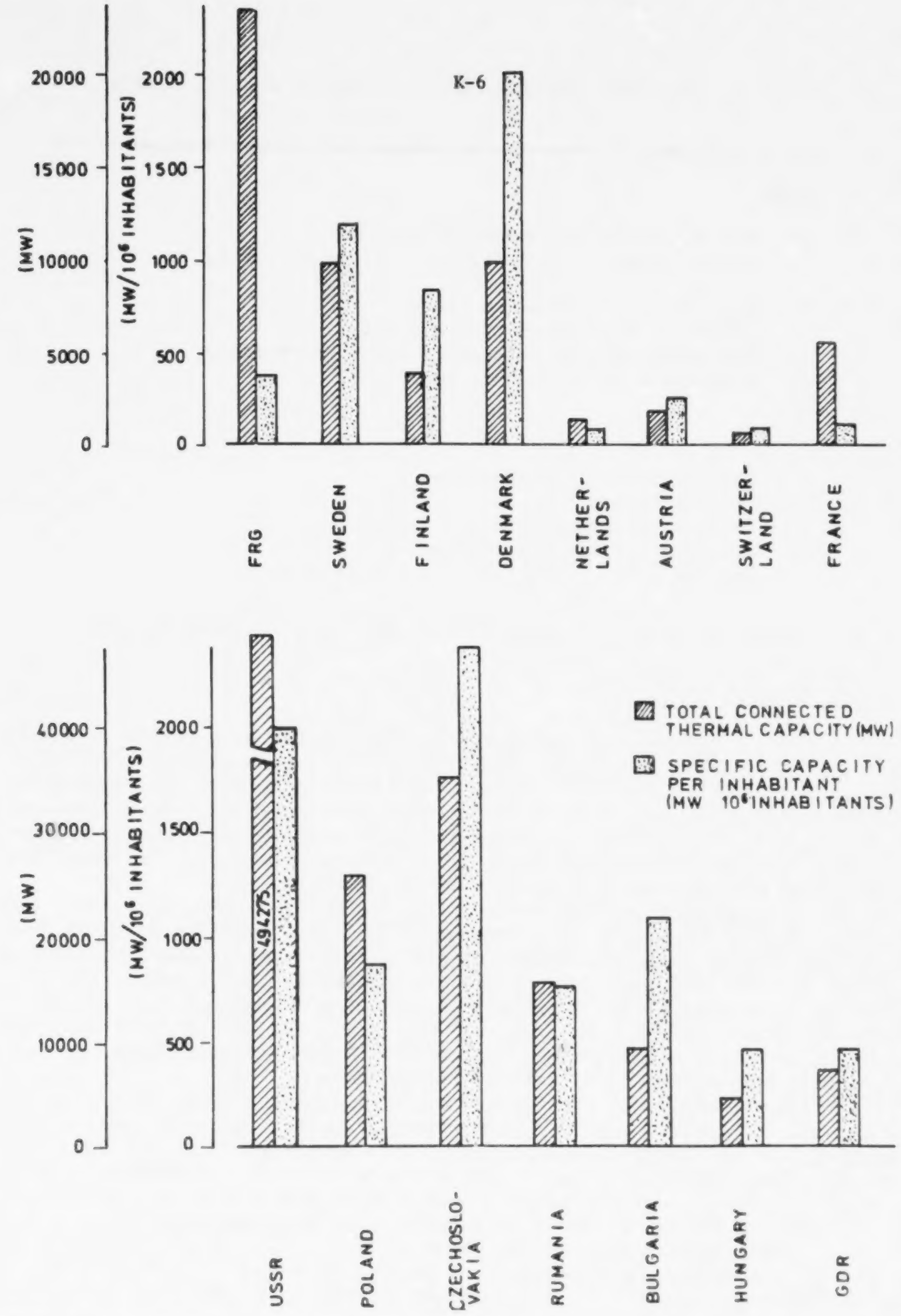


FIGURE K-1. CONNECTED AND SPECIFIC CAPACITIES IN EUROPE (Courtesy of Lennart Lindenberg AB Energi Konsult at this Swedish district heating workshop obtained from Scholten, Timm. Survey of Existing District Heating Systems. Nuclear Technology. Vol. 38) control equipment or to close. Many have chosen to close. Often systems spend money on emissions cleanup but let the steam lines fall into disrepair.

It is the opinion of these researchers that the issues raised in the above two paragraphs have unnecessarily soured decision maker attitudes in America to the detriment of full consideration of Refuse-Fired District Heating Systems.

A persuasive argument for district heating is highlighted in Figure K-2. If each single family house has its own oil fired furnace, the community heating efficiency is about 50-60 percent. However, under the distric heating apartment building arrangement, the efficiency rises to 70-80 percent. This high district heating efficienty is achieved despite 3 to 10 line efficiency losses.

District Heating, however, is not necessarily desirable for all applications as to shown in Table K-5. It is normally "very favorable" for downtown, high rise buildings. Even though the table states that it is "not possible" to provide D.H. for one family houses, it occasionally is provided in several Denmark and other country locations including Gothenburg.

Erik Wahlman of Sweden's consulting firm of Theorell & Marin suggests uses of the form of Figure K-3 when planning a D.H. system. He has found out that in Sweden, various types of buildings have different heat and energy requirements per unit area and have different energy demand patterns (hours per day and year). (See Table K-6.)

Figure K-4 of Mr. Wahlmman's shows how the average and maximum head demand varies by month over a year in Sweden. Notice that excersions to the maximum are more pronounced. The average monthly heat demand is slightly more stable.

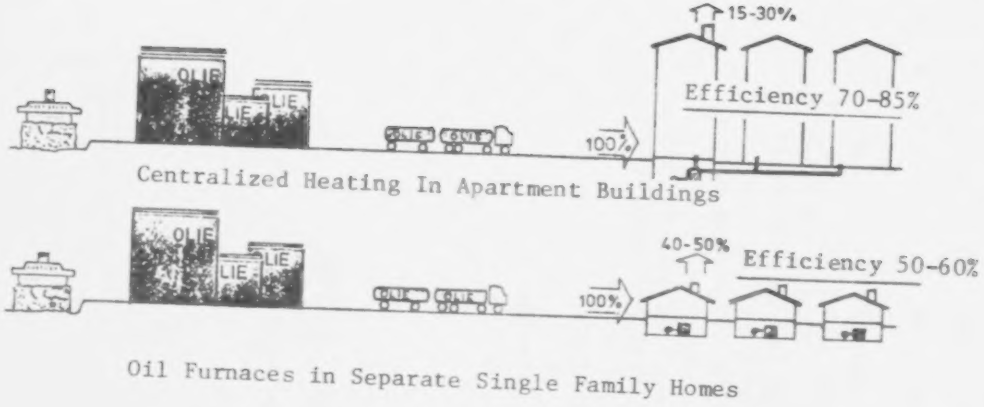
Table K-7 presents several local market factors which should favor the installation of district heating steam and chilled water systems in an American situation.

District Cooling (Not Observed in Europe)

In 1973, Battelle performed a study of the potential for refuse fired district heating and cooling systems across the U.S.A. The study concluded that there were definite economic benefits to the system if district cooling could be provided in the Summer. The Nashville Thermal Transfer Corporation in Nashville, Tennessee was the model for that study.

Technically, the district cooling can be accomplished in either of two ways. In Nashville, steam is sent to an adjoining Carrier chiller station equipped with large turbines, compressors and condensers. Cold water at 5 C (41 F) is then pumped to over 30 downtown office buildings. The other method that might be used in about to be demonstrated by the Harrisburg Incinerator Authority in Pennsylvania. In that case hot steam continues to be sent through the lines in the Summer. Building owners who desire air cooling then direct steam to their own adsorption chilling stations--one in each basement.

The Nashville unit had adversely affected the reputation of the entire mass burning industry due to its under-capitalization and technical start up problems. Even in 1978, many think of these problems when they think of Nashville. Table K-8 presents very positive recent finanacial data that vindicate the original developers and support the forward thinking by officials of Nashville that sought corrective bonding.


15-30%
OLIE
LIE
LIE
OLIE
100%
Efficiency 70-85%
40-50%
Efficiency 50-60%

Centralized Heating In Apartment Buildings

Oil Furnaces in Separate Single Family Homes

FIGURE K-2. SCHEMATIC SHOWING HOW A CENTRAL DISTRICT HEATING SYSTEM COMPARES IN EFFICIENCY WITH INDIVIDUAL HOME HEATING SYSTEMS

TABLE K-5. ATTRACTIVENESS OF DISTRICT HEATING AS A FUNCTION OF DENSITY OF ENERGY USE(a)

Peak Density MM Btu/hr-acre	Average Corrected Load Density MM Btu's/yr-acre	Type of Land Use (Typical)	Attractiveness (Relative)
0.97	> 2470	Downtown, high-rise	Very favorable
0.70-0.97	1782 to 2470	Downtown, multi-story	Favorable
0.28-0.70	713 to 1780	City Core, Commercial or multi-family apartment	Possible
0.17-0.28	433 to 713	Residential, four two-family houses	Questionable
0.17	< 433	One family houses	Not possible

(a) This reference presented data in units of millions of Btu's per hour-acre/at peak load. This interpretation of the data was confirmed with Dr. Michael A. Karnitz of ORNL in a telephone conversation November 3, 1978.

Average load may be approximated by:

$$\frac{\text{MM Btu peak/hr-acre (24 hr/day) (6366 heating degree days/yr)}}{\text{(60 heating degree days/day at peak)}}$$

or $$\frac{\text{2546.4 MM Btu/year average}}{\text{MM Btu/hr peak}}$$

Thus, the data in the reference were converted from MM Btu(hr-acre/peak) to MM Btu/yr-acre (average) by multiplying by 2546.4.

Source: Wahlman, Erik, "Energy Conservation Through District Heating- A Step by Step Approach," Swedish District Heating Workshop, October 1978, p.7.

Firm or Owner ....
Adress ....
Person interviewed ....

BUILDING HVAC SYSTEM SURVEY
SIC code or type of establishment ....
Age of building ....

	EXISTING/ NOT EXISTING	TEMP. PRESSURE	CAPACITY MBTU/HR	ANNUAL DEMAND MBtu	YEAR INSTALLED	YEARS TO RETIREMENT	REMARKS
Connected to central steam distribution system	Yes/No			-			
Steam/boiler	Yes/No						
HW boiler	Yes/No						
Steam distribution system:	-	-	-	-	-	-	
- in boiler room only	Yes/No						
- to mechanical rooms throughout building	Yes/No						
- to radiation system	Yes/No						
HW system to heating coils	Yes/No						
HW radiation system	Yes/No						
Induction unit/fan coil unit system	Yes/No						
Central chilled water generation:	-				-	-	
- Reciprocating	Yes/No						
- Centrifugal/screw	Yes/No						
- One/two stage absorption	Yes/No						
DX - cooling	Yes/No						
Gas fired ventialtion units	Yes/No						
Steam/HW/gas/electric dom. hot water heater							

Note: When systems have been installed in phases, define data for each phase.

Interviewr's name ....   Date ....

(Courtesy of Erik Wahlman, Theorell & Martin given at the Swedish District Heating Workshop)

FIGURE K-3

TABLE K-6. SPECIFIC HEAT AND ENERGY NUMBERS OF DIFFERENT TYPES OF SWEDISH BUILDINGS
(Annual Averages)

Type	Heat		Total Energy		Duration	
	Watts/m^2	Btus/hour-ft^2	kwh/m^2	1000 Btu/ft^2	hours/day	hours/year
Office	120	38	180	57	15	1500
Stores	120	38	180	57	15	1500
Old Apartments	80	25	240	76	21	3000
New Apartments	67	21	200	63	21	3000
Houses	83	26	200	63	18	2400
Hospitals	70	22	210	66	21	3000
Schools	82	26	180	57	18	2200
Industry	167	53	250	79	15	1500

SOURCE: Erik Wahlman President of Theorell & Martin Energi Konsulter AB at the Swedish District Heating Workshop, October 1978.

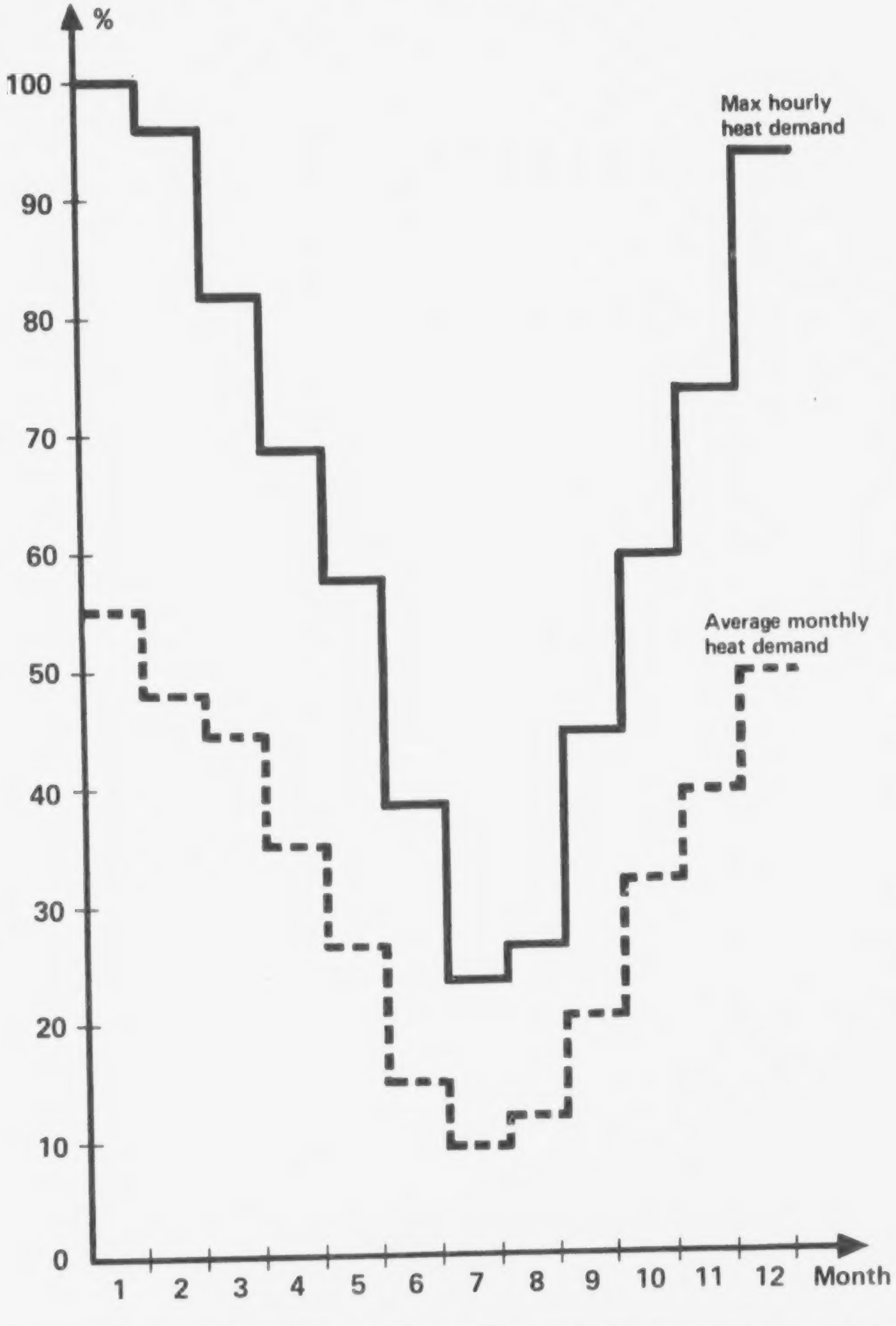


FIGURE K-4. MAXIMUM HOURLY HEAT DEMAND AVERAGE MONTHLY HEAT DEMAND (Courtesy of Erik Wahlman, Theorell & Martin Energikonsulter AB at the Swedish District Heating Workshop)

TABLE K-7. FAVORABLE DEMAND ASPECTS OF DISTRICT HEATING AND COOLING SYSTEMS IN THE U.S.A.

1. Large, dense load area
2. Land available for system
3. Sufficient initial customers to assure adequate load
4. Urban renewal slated or under way
5. Location in state capital
6. Local coal-burning steam utility desiring to leave business because of pollution regulations
7. Local district heating utility desiring to increase business with addition of chilled water
8. Increasing conventional fuel prices
9. Uncertain conventional fuel availability
10. Lack of interest in solid waste for electrical generation of industrial steam
11. Flexible rate setting for district heating and cooling products

TABLE K-8. REPORT ON OPERATIONS NASHVILLE THERMAL TRANSFER CORPORATION FOR THE TWELVE MONTH PERIOD ENDING MAY 31, 1978

Condensed Statement
Disposition of Revenues

	12 Months Ended	
	5-31-78	5-31-77
Steam: Heating	$ 1,418,361	$ 1,448,093
Water: Cooling	1,473,017	1,433,864
Total Operating Revenues	$ 2,891,378	$ 2,881,957
Total Operating Expenses	1,926,750	1,936,643
Net Operating Revenues	$ 964,628	$ 945,314
Payment From Metropolitan Government of Nashville and Davidson County	1,300,000	1,275,000
Other Income	47,915	69,442
Balance for Debt Service	$ 2,312,543	$ 2,239,756
Total Debt Service	1,943,843	1,838,127
Balance Or (Deficiency) After Debt Service	$ 363,700	$ 451,629
Coverage (Balance for Debt Service/Total Debt Service)	$ 1,187	$ 1,246

Comparative Data

	5-31-78	5-31-77
Number of Customers Billings (Average Per Month) (**):		
Steam	$ 15	$ 15
Cooling	18	18
Sales Volume:		
Steam -		
Demand (Pounds Per Hour) (*)	$ 178,490	$ 176,805
Commodity (Thousand Pounds)	230,218	236,204
Cooling -		
Demand (Tons) (*)	8,665	8,625
Commodity (Thousand Ton-Hours)	19,109	18,234
Refuse Incinerated (Tons)	140,973	134,586

(*) Peak Demand During 12 Month Period.

(**) The buildings served are over 30 in total. The State of Tennessee, for example, has over 6 buildings but is considered only 1 customer.

Without question, in the total subject area of refuse to energy, the technology flow needs to be from Europe to U.S.A. However, those Europeans who desire to increase Summer loads and overall financial results might do well to look at district heating and cooling as practiced in Nashville, Tennessee, and Harrisburg, Pennsylvania.

Underground Distribution

Every district heating system viewed had unique underground pipe distribution schemes. In all hot water systems, there is a return warm water pipe. However in steam systems, the designers have a choice of returning condensate or not. Many designers fear the corrosive effect of the returning condensate. Others wish to conserve water and will try to design to minimze corrosion.

All hot water and some steam systems viewed had packed tunnels, i.e., packed with dirt, gravel, insulation, etc. See Figured K-5a, b, c, and d. Several steam systems, however, use human walk through tunnels such as detailed later at Zurich. Duesseldorf, because of the railroad and other underground utilities, uses an overhead pipe as shown later.

Figures K-6a, b, c, and d and Figures K- 7a, b, c, and d describe some of the Swedish piping alternatives in greater detail. The Wirsbo Bruk people now offer plastic high density polyethylene pipe (Figures K-8, K-9, and K-10). If the underground pipes are usually above the water table, mineral wool insulation may be used. Otherwise, they recommend their foamed polyurethane sections.

Another system available is the Aquawarm polyethlene encased copper hot water and return pipes shown in Figure K-11a, b, and c. The sinusoidal laying is for expansion and contraction as the ambient temperature changes.

The final pipe system described in this report offered by TK-ISOBIT is a steel pipe encased in bituminous concrete and swathed in an impregnated cellulosic filler as shown in Figure K-12. The 6 m (19 feet) sections are welded and bituminous concrete is also poured on the joint.

Community Electrical Power District Heating and Cooling Development

During the period October 10-20, 1978, the Swedish Trade Office in Chicago produced a series of Swedish District Heating Workshops in major American cities. Speakers were vendors, consultants and officials from the Swedish Government. They distributed proceedings which can be purchased for $30.00 by writing to:

Per-A, Sjolund, Trade Commissioner
or Torbjorn Lindahl, Project Manager
Swedish Trade Commission
333 N. Michigan Avenue
Chicago, Illinois 60601

A few of the diagrams and insights contained will be presented in the following pages.

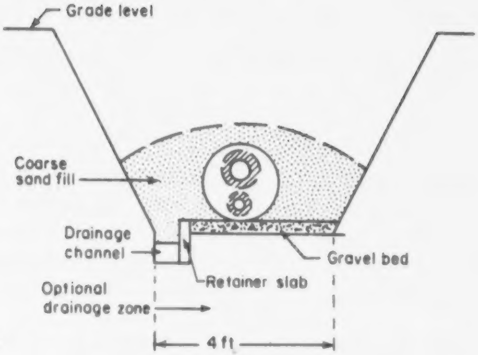

Grade level
Coarse sand fill
Drainage channel
Gravel bed
Retainer slab
Optional drainage zone
4 ft

FIGURE K-5a. STEAM DISTRIBUTION AND RETURN CONDENSATE PIPES AT WERDENBERG

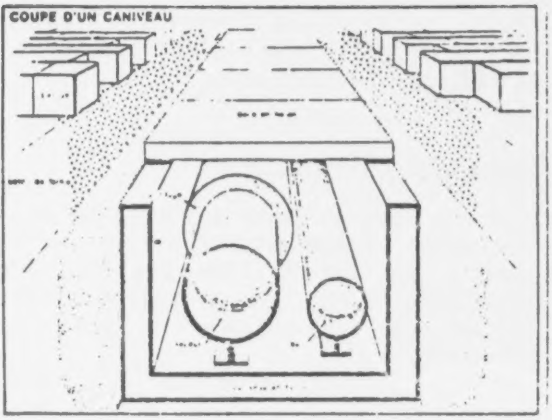

COUPE D'UN CANIVEAU

FIGURE K-5b. STEAM DISTRIBUTION AND RETURN CONDENSATE PIPES AT PARIS

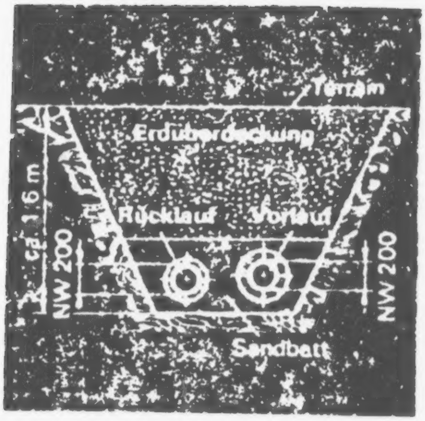
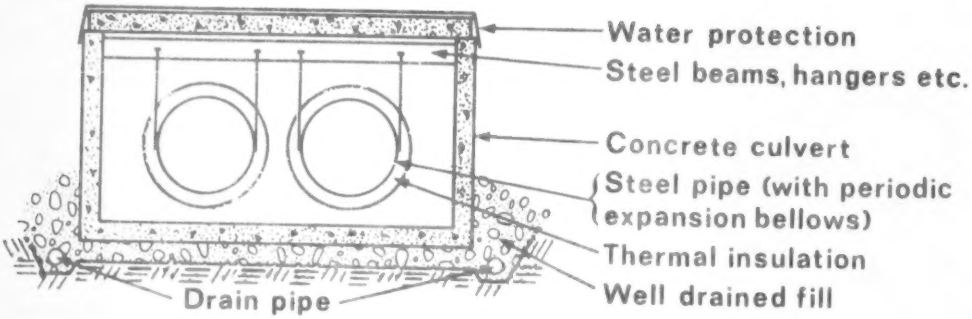

Terrain
Erdüberdeckung
Rücklauf
Vorlauf
ca 1,6 m
NW 200
NW 200
Sandbett

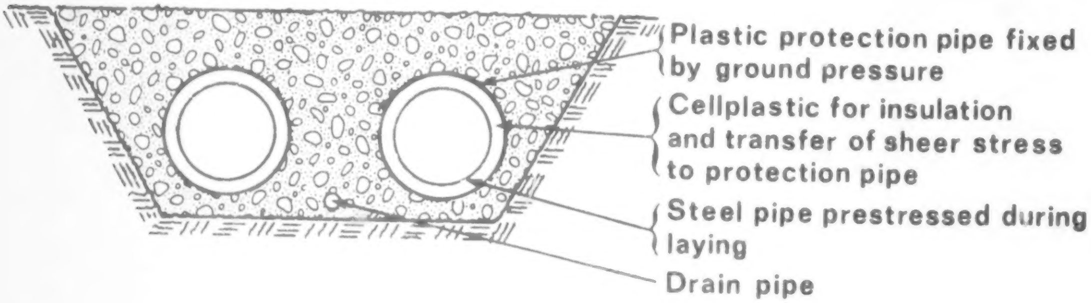
FIGURE K-5c. HOT WATER PIPES AT WERDENBERG

FIGURE K-5d. HOT WATER PIPES AT UPPSALA

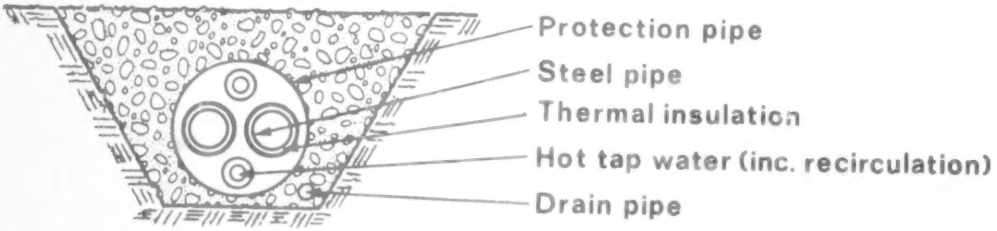
a) Large pipes


Water protection
Steel beams, hangers etc.
Concrete culvert
Steel pipe (with periodic expansion bellows)
Thermal insulation
Well drained fill
Drain pipe

b) "Pipe in pipe" system


Plastic protection pipe fixed by ground pressure
Cellplastic for insulation and transfer of sheer stress to protection pipe
Steel pipe prestressed during laying
Drain pipe

c) Multiple pipe system


Protection pipe
Steel pipe
Thermal insulation
Hot tap water (inc. recirculation)
Drain pipe

d) "Aqua warm" system

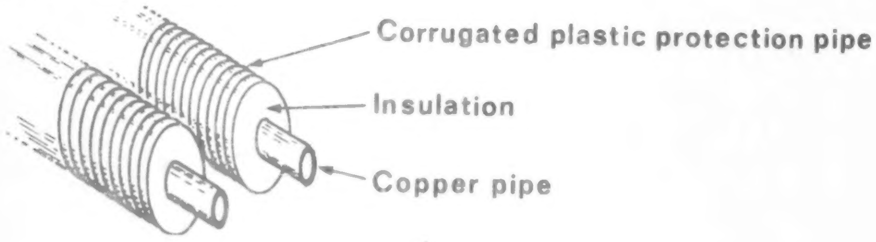

Corrugated plastic protection pipe
Insulation
Copper pipe

FIGURE K-6. CONVENTIONAL HOT WATER DISTRIBUTION PIPES

(Courtesy of AB Energikonsult given at the Swedish District Heating Workshop)

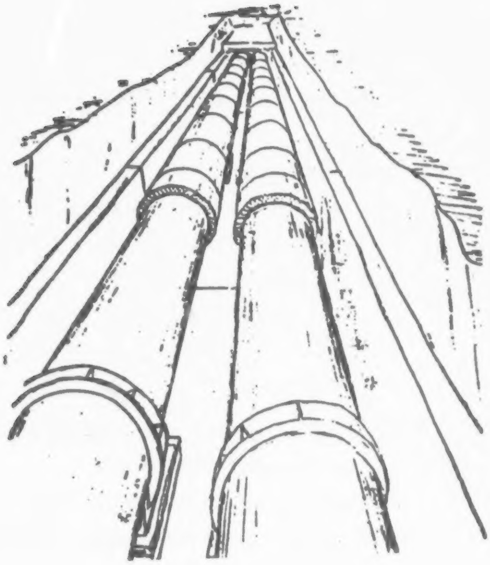
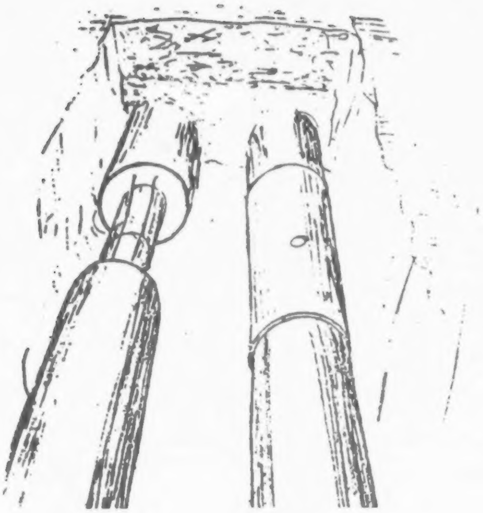


FIGURE K-7a. CONCRETE CULVERT



PLASTIC K-7b. PLASTIC PIPE CONVERT

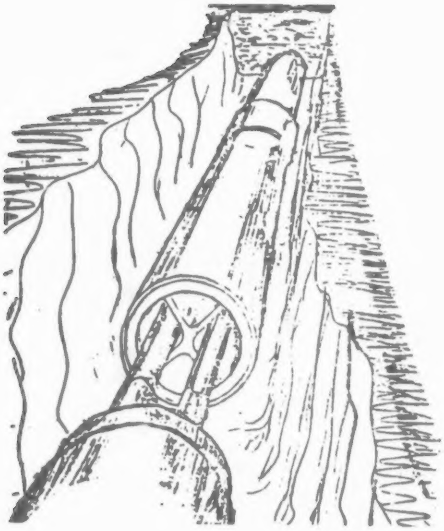


FIGURE K-7c. ASBESTOS CEMENT PIPE CULVERT

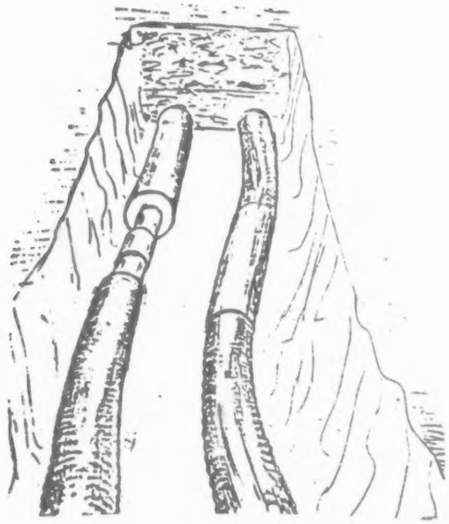


FIGURE K-7d. COPPER PIPE CULVERT

FIGURE K-7

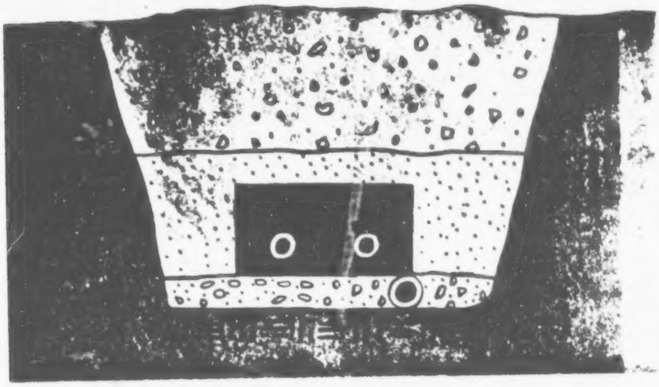
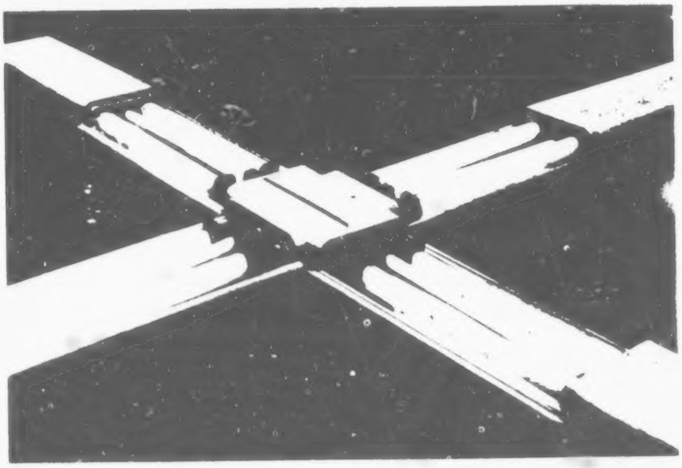


FIGURE K-8. DESIGN OF THE TRENCH WHEN THE PIPE IS INSULATED WITH MINERAL WOOL

The total thickness of the backfill above the insulation should be about 8" (20 cm).

FIGURE K-9. DESIGN OF THE TRENCH WHEN THE PIPE IS INSULATED WITH WIRSBO-PUR (POLYETHYLENE PIPE)

The total thickness of the backfill above the insulation should be about 20" (50 cm).



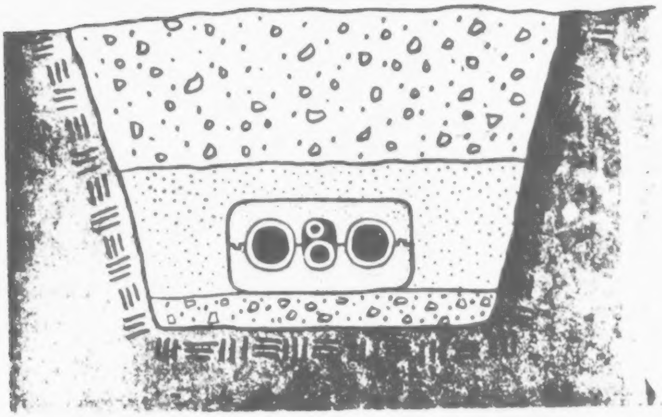


FIGURE K-10. WIRSBO-PEX POLYETHYLENE PIPE AND WIRSBO-PER INSULATION PRE-FABRICATED PARTS AT A JUNCTION BOX

(These figures are the courtesy of Walter Engelhardt, Wirsbo Bruk given at the Swedish District Heating Workshop)

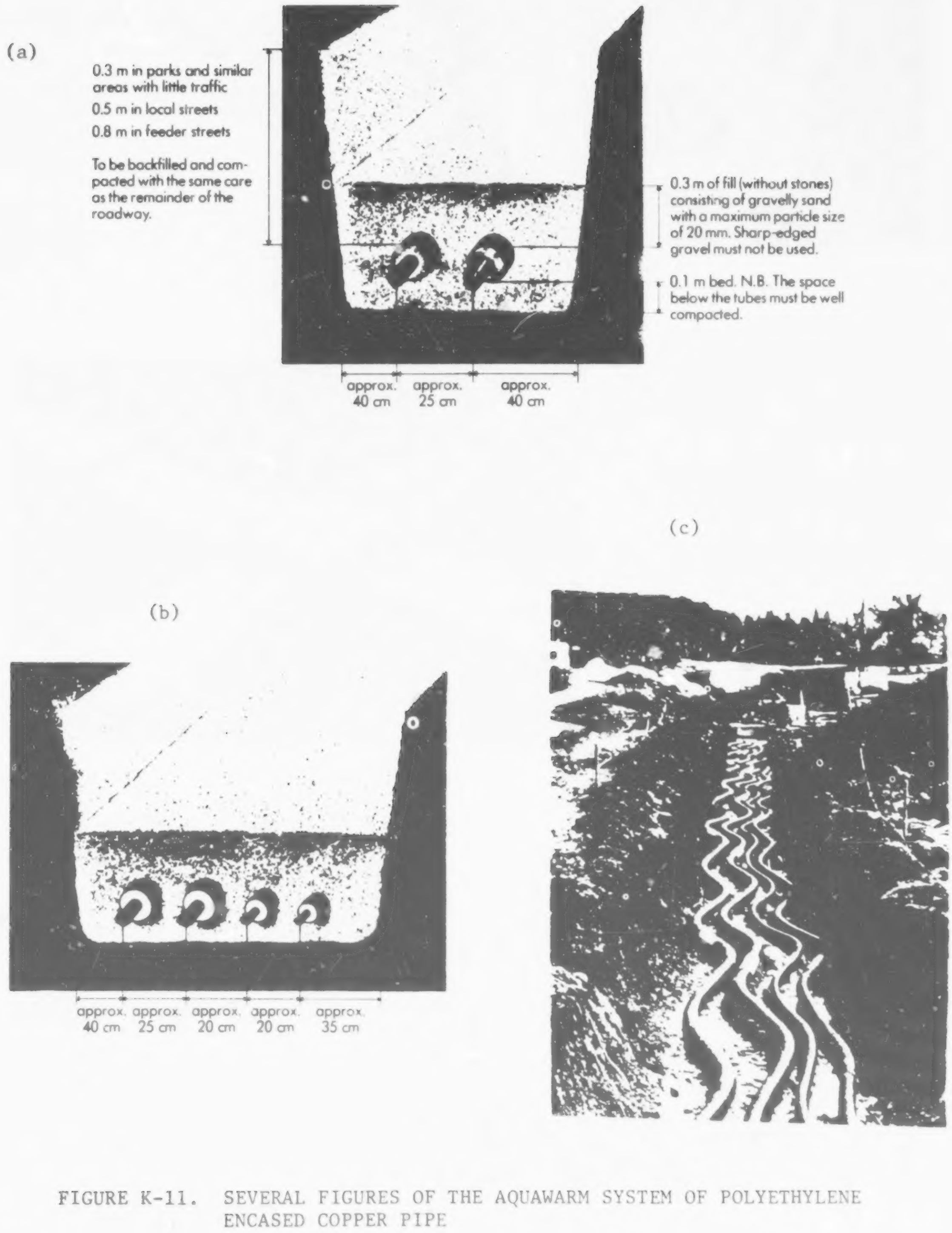
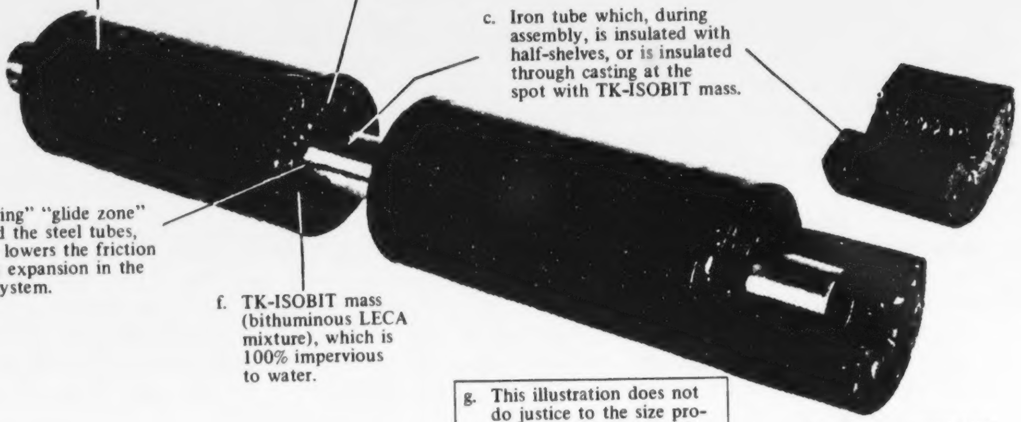

(a)
0.3 m in parks and similar areas with little traffic
0.5 m in local streets
0.8 m in feeder streets
To be backfilled and compacted with the same care as the remainder of the roadway.
0.3 m of fill (without stones) consisting of gravelly sand with a maximum particle size of 20 mm. Sharp-edged gravel must not be used.
0.1 m bed. N.B. The space below the tubes must be well compacted.
approx. 40 cm
approx. 25 cm
approx. 40 cm
(c)
(b)
approx. 40 cm
approx. 25 cm
approx. 20 cm
approx. 20 cm
approx. 35 cm

FIGURE K-11. SEVERAL FIGURES OF THE AQUAWARM SYSTEM OF POLYETHYLENE ENCASED COPPER PIPE



a. Housing tube made of tar-impregnated cellulose fiber. Tar has a bacteria-destroying effect.

b. The asphalt in the TK-ISOBIT mass has a self-healing effect, so that notches or fissures that might be caused by jerks or accidents, will fuse and close, The insulation layer remaining uninterrupted.

d. The TK-ISOBIT insulation mass has the following heat transmission coefficient λ:
0.11 kcal/m·h·°C.

c. Iron tube which, during assembly, is insulated with half-shelves, or is insulated through casting at the spot with TK-ISOBIT mass.

e. "Flowing" "glide zone" around the steel tubes, which lowers the friction during expansion in the tube system.

f. TK-ISOBIT mass (bithuminous LECA mixture), which is 100% impervious to water.

g. This illustration does not do justice to the size proportions. Normal length per tube section: 6 meters (see photograph of the production hall).

h. Stand: operational temperature above 150°C.

FIGURE K-12.

One of the basic premises of community district heating development is that it progress in stages. Five key stages are shown in Figure K-13 and are as follows:

Stage 1: Consumer system
Stage 2: Portable oil or gas fired central stations
Stage 3: Permanent district heating stations
Stage 4: Cogeneration of electricity and district heat (sometimes with refuse)
Stage 5: Base load with distant nuclear waste heat

Another example is the staged development of the Sodertalje district heating system as shown in Figure K-14.

Piping is installed in stages as well as depicted in the 20 years annual investment pattern shown for Sodertalje in Figure K-15.

Stage 1: Consumer Systems. Erik Wahlman in his paper on "Conversion of Heating Systems in U.S. Buildings", suggests that almost any existing energy plant can be retrofitted for hot water district heating. As examples, Figures K-16a and K-16b are included for conversion of ventilating and radiator systems.

Stage 2: Portable Oil or Gas Fired Central Sub Station. Figure K-17 shows a portable oil fired district (or Central) heating substation. Often they have fire-tube boilers as shown in Figure K-18. A station might be erected for a subdivision. When two to five of these are in an area it becomes economical to erect a permanent district station. These portable units can then be moved to another community.

Stage 3: Permanent District Heating Station. An example of a permanent district heating station is to be found in Figure K-19 at Copenhage: West. Later in Stages 4 or 5, these stations can be used in two ways as portrayed in the tails of Figure K-20. First, when another source is providing the baseload, the permanent boilers can be used for peaking. Second, When there is either not enough refuse input or energy demand output, the oil-fired boilers can be used instead of firing the expensive to operate base load refuse fired energy plant.

Stage 4: Cogeneration of Electricity and District Heating (sometimes with refuse). Inferred in the previous figure, a refuse-fired cogeneration facility could provide the base load. Repeatedly on the European tour and during the Swedish District Heating Workshop mention was made of other advantages of cogeneration. Two figures demonstrate the advantage. Figure K-21 presents schematics showing a simple power station with a condensing turbine that must waste much energy in a condenser. It also shows the more energy efficient cogeneration plant that has a back pressure turbine to provide electricity and steam or hot water for district heating. The lower Figure K-22 shows the system efficiency rising from 36 percent in the simple power station to 86 percent in the cogeneration plant.

In a similar manner, Carl-Erik Lind, head of the energy section at the Swedish National Board of Industry presented Figure K-23 showing the percentages. With a slight derating of the electrical output (from 40 percent

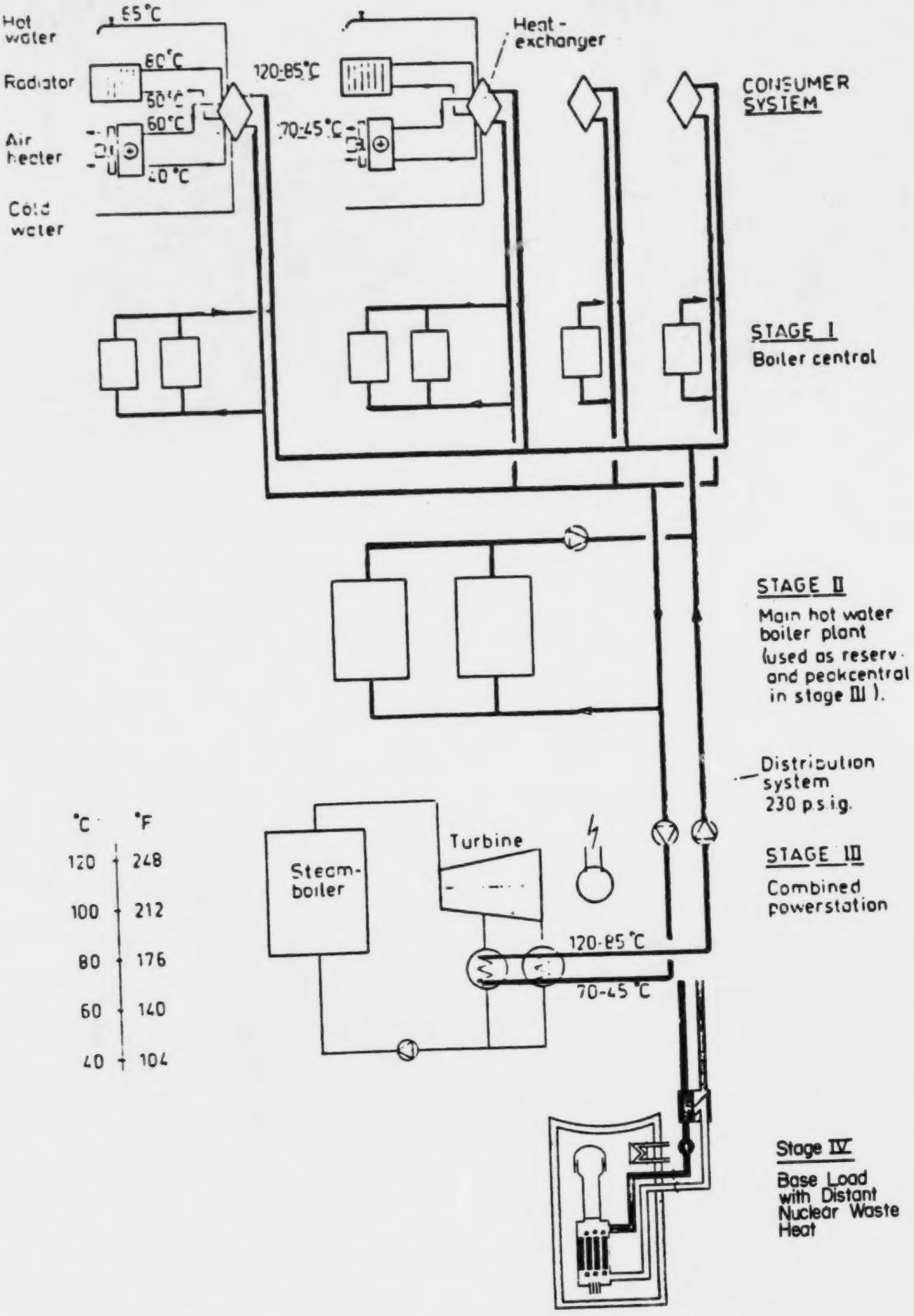
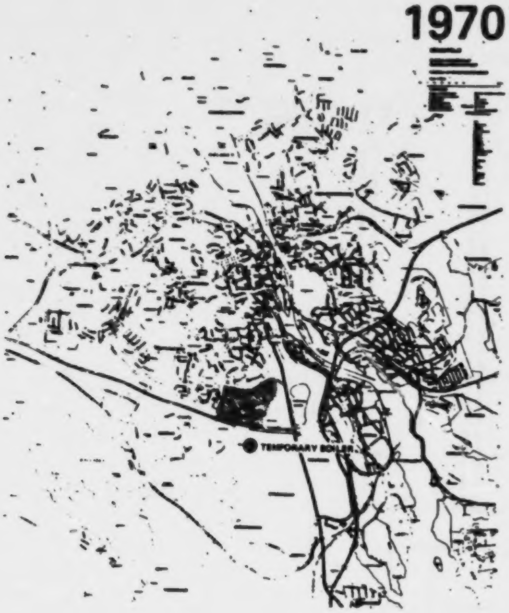
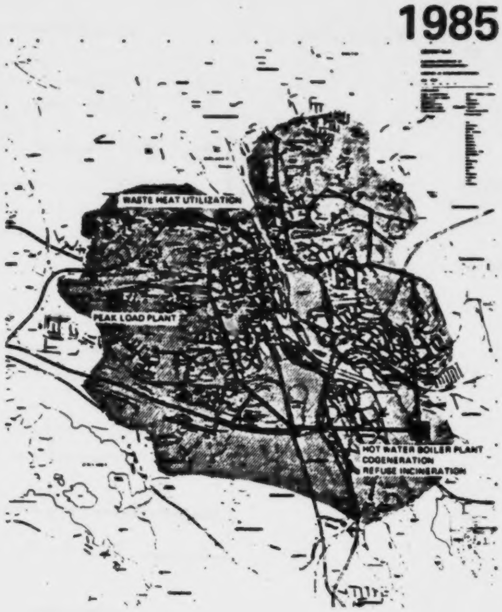

Hot water
55°C
Radiator
80°C
50°C
60°C
Air heater
40°C
Cold water
120-85°C
70-45°C
Heat-exchanger
CONSUMER SYSTEM
STAGE I
Boiler central
STAGE II
Main hot water boiler plant
(used as reserv. and peakcentral in stage III).
Distribution system
230 p.s.i.g.
STAGE III
Combined powerstation
Steam-boiler
Turbine
120-85°C
70-45°C
°C
°F
120
248
100
212
80
176
60
140
40
104
Stage IV
Base Load with Distant Nuclear Waste Heat

FIGURE K-13. TOTAL ENERGY PLAN BUILT UP IN THREE STAGES

(Courtesy of Erik Wahlman, Theorell & Martin Energi Konsulter AB at the Swedish District Heating Workshop)


1970
TEMPORARY BOILER


1985
WASTE HEAT UTILIZATION
PEAK LOAD PLANT
HOT WATER BOILER PLANT
COGENERATION
REFUSE INCINERATION

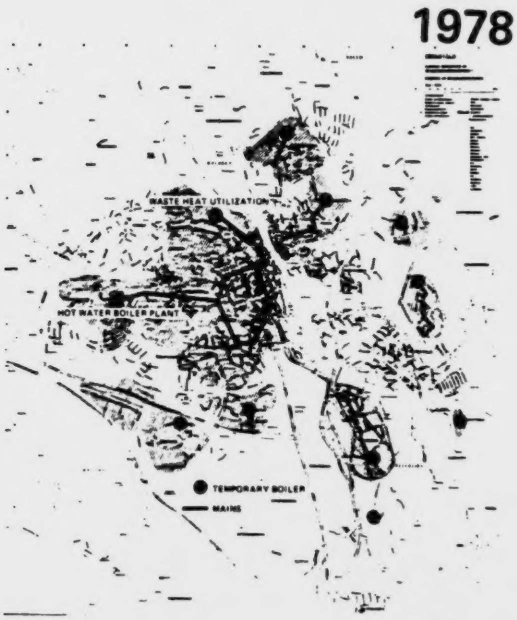

1978
WASTE HEAT UTILIZATION
HOT WATER BOILER PLANT
TEMPORARY BOILER
MAINS

FIGURE K-14. STAGED DEVELOPMENT OF DISTRICT HEATING IN SÖDERTALJE

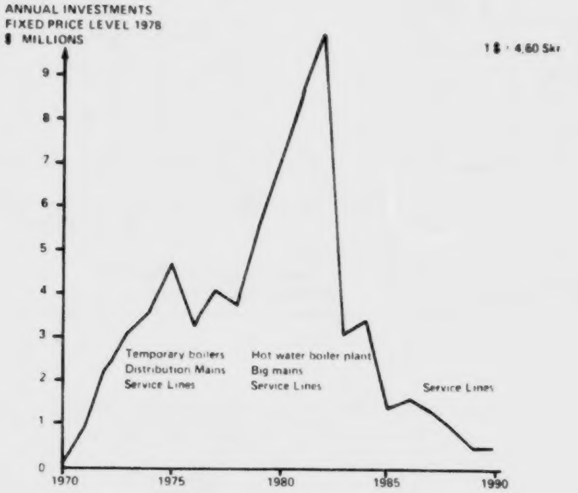


FIGURE K-15. ANNUAL CAPITAL INVESTMENT AT THE CITY OF SODERTALJE ENERGY AUTHORITY

(Courtesy of Tomas Bruce, City of Sodertalje Energy Authority given at the Swedish District Heating Workshop)

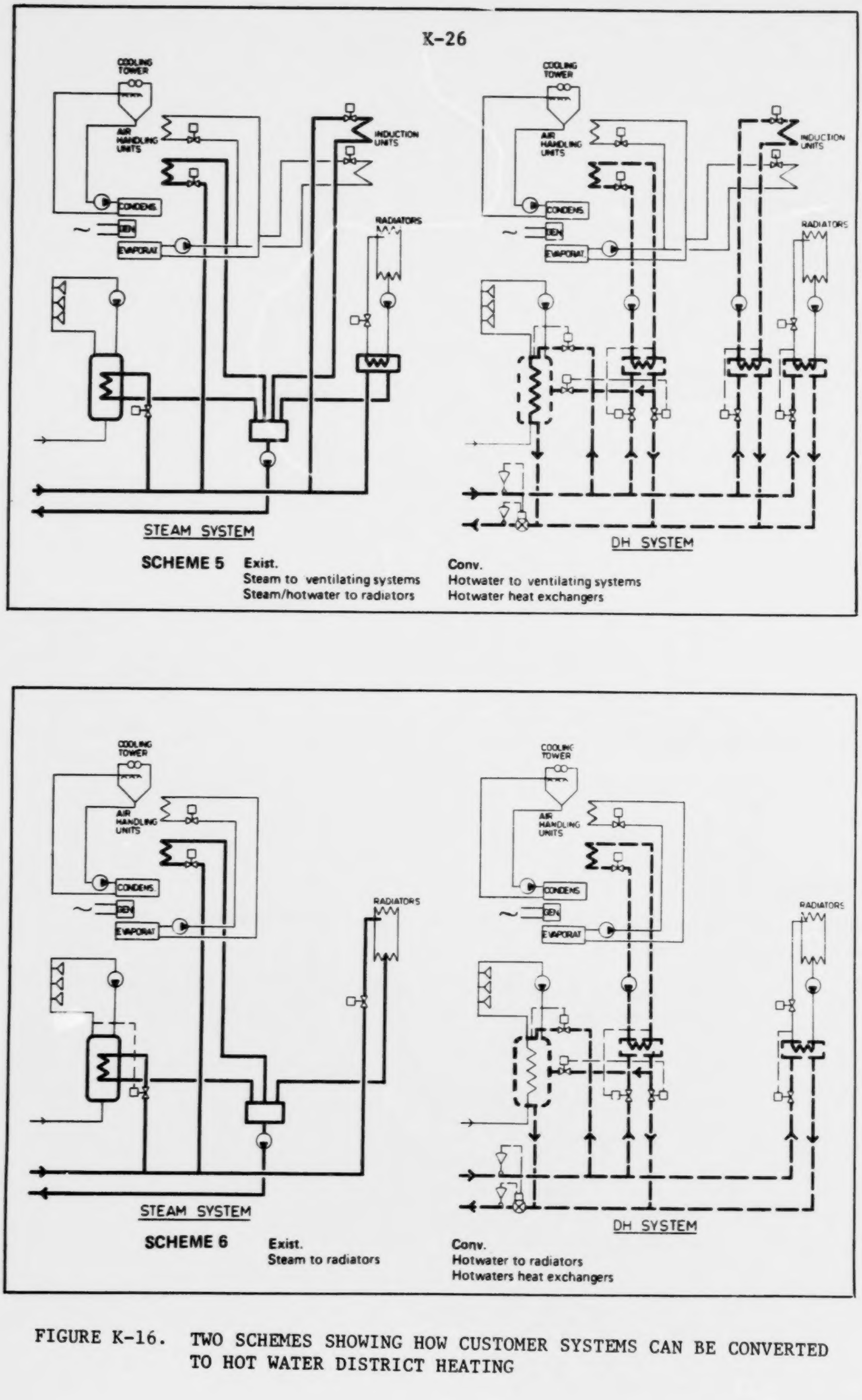

COOLING TOWER
AIR HANDLING UNITS
INDUCTION UNITS
CONDENS.
GEN
EVAPORAT
RADIATORS
STEAM SYSTEM
DH SYSTEM
SCHEME 5
Exist.
Steam to ventilating systems
Steam/hotwater to radiators
Conv.
Hotwater to ventilating systems
Hotwater heat exchangers
(a)
COOLING TOWER
AIR HANDLING UNITS
CONDENS.
GEN
EVAPORAT
RADIATORS
STEAM SYSTEM
DH SYSTEM
SCHEME 6
Exist.
Steam to radiators
Conv.
Hotwater to radiators
Hotwaters heat exchangers
(b)

FIGURE K-16. TWO SCHEMES SHOWING HOW CUSTOMER SYSTEMS CAN BE CONVERTED TO HOT WATER DISTRICT HEATING

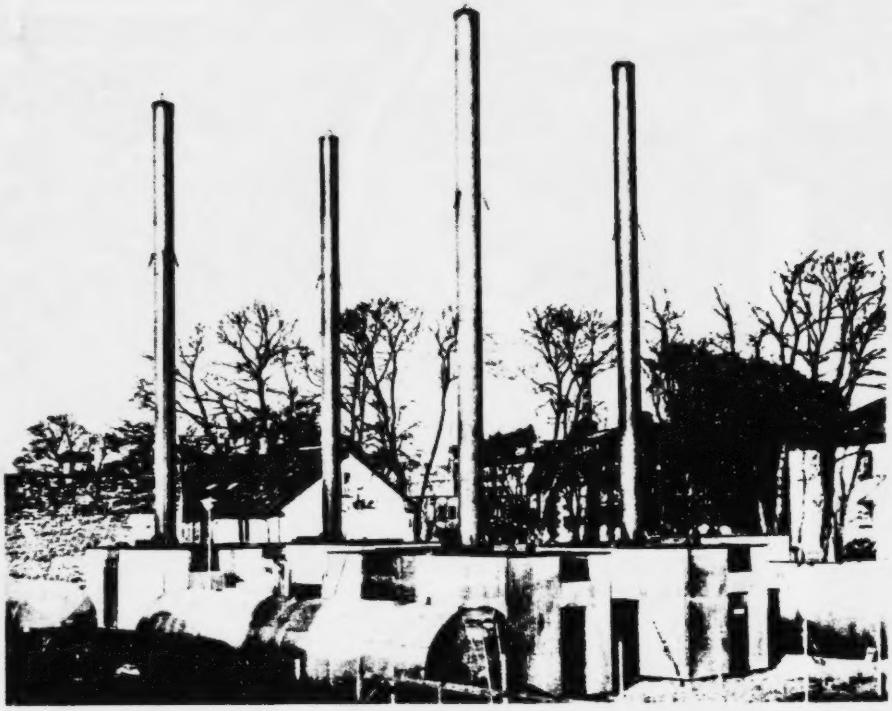


FIGURE K-17. PORTABLE OIL-FIRED DISTRICT HEATING SUB STATION

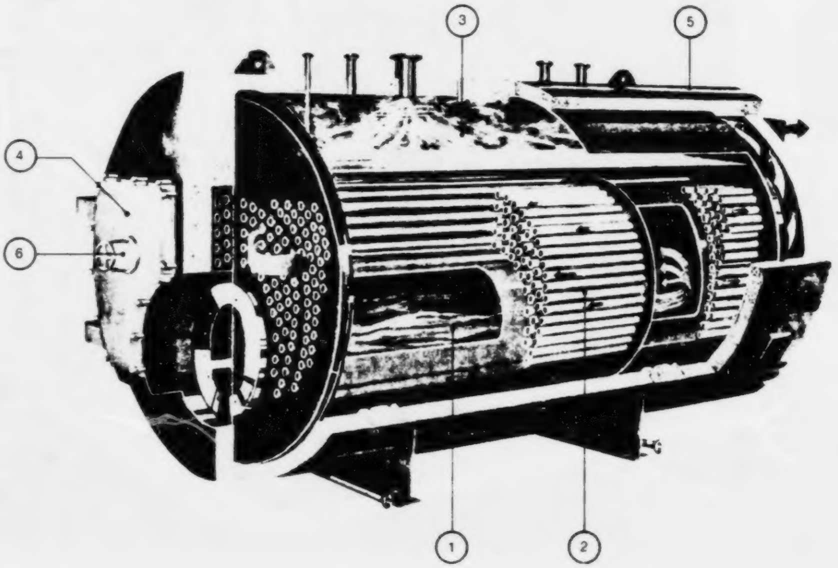


FIGURE K-18. PORTABLE OIL-FIRED FIRE-TUBE BOILER (Courtesy of Jan-Olof Djärv, A B Energi Konsult given at the Swedish District Heating Workshop)

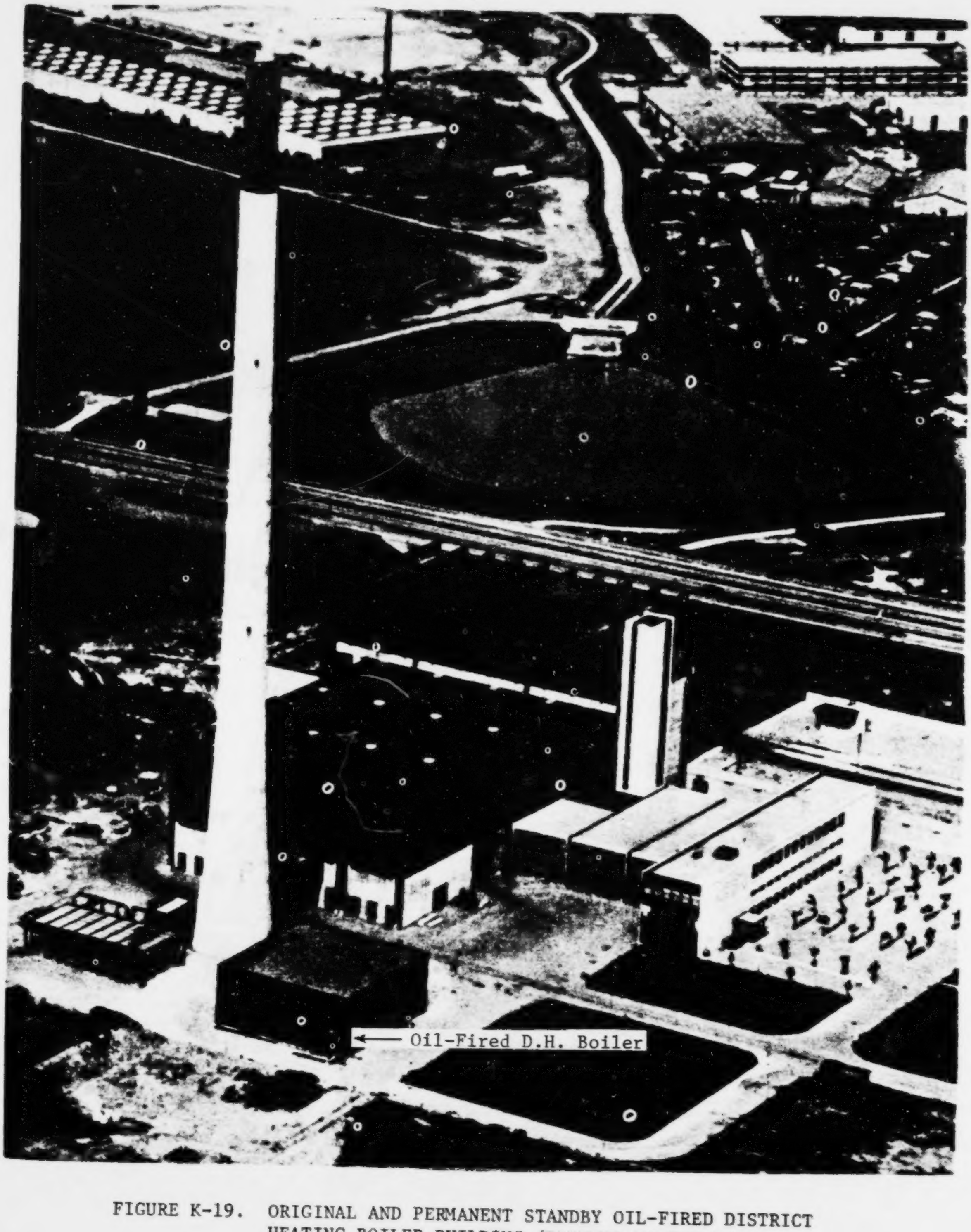

Oil-Fired D.H. Boiler

FIGURE K-19. ORIGINAL AND PERMANENT STANDBY OIL-FIRED DISTRICT HEATING BOILER BUILDING (DWARFED BY THE LARGE REFUSE-FIRED HOT WATER GENERATOR)

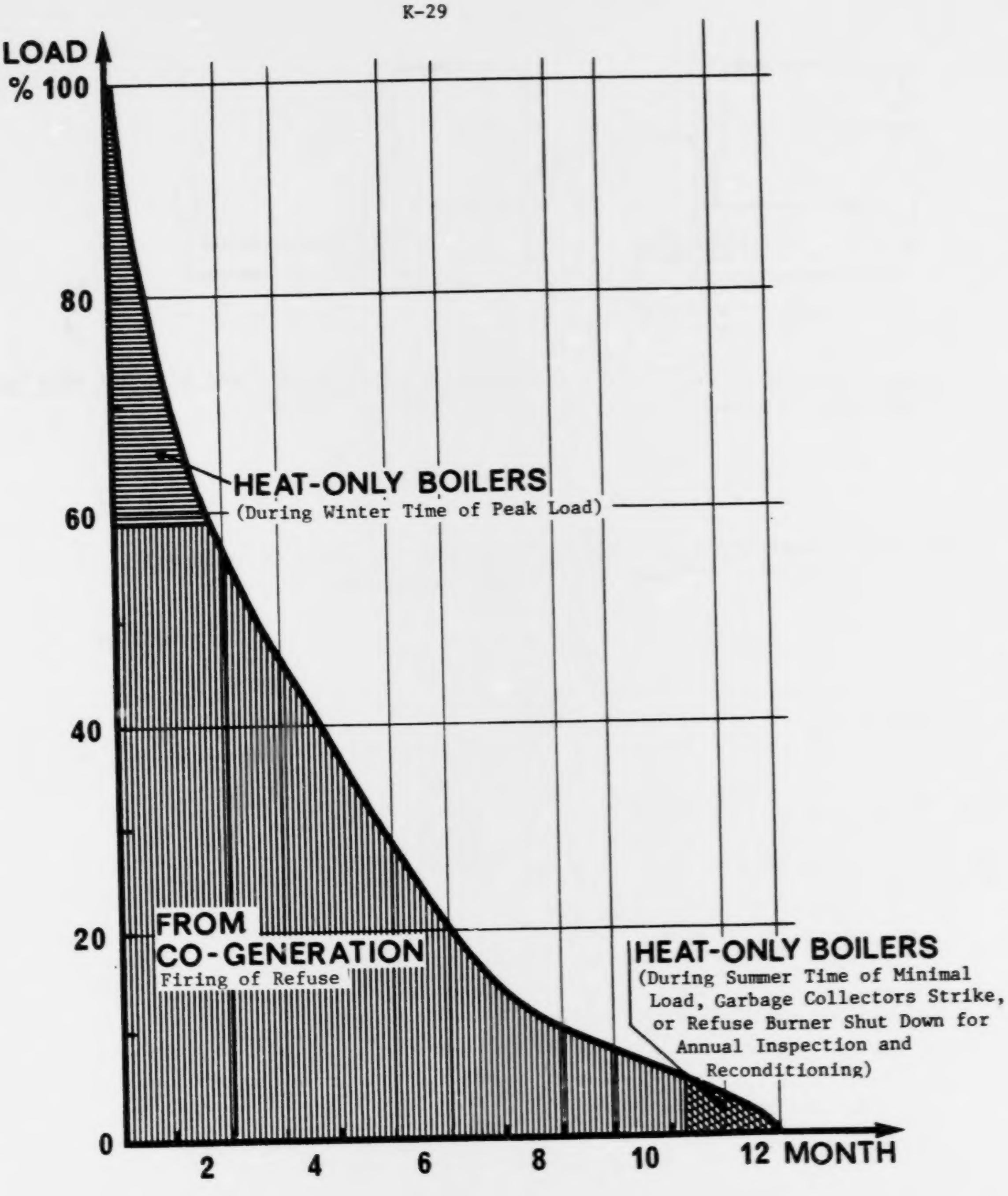
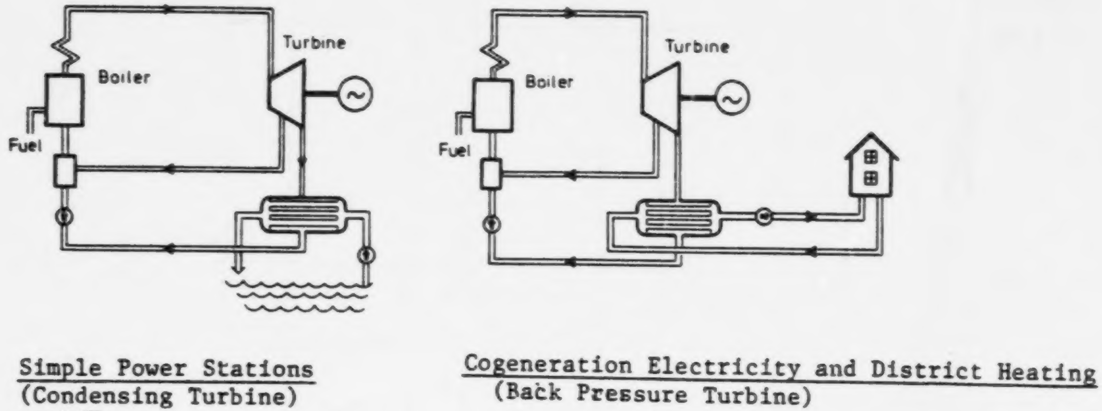


FIGURE K-20, HEAT LOAD DURATION CURVE AND LOAD-SPLIT. HEAT ONLY PACKAGE BOILERS USED (1) FOR PEAKING, (2) WHEN THERE IS NOT ENOUGH REFUSE SUPPLY (3) WHEN ENERGY DEMAND IS TOO LOW OR (4) DURING SHUT DOWN FOR INSPECTION AND RECONDITIONING (Modification Studsvik Energiteknik AB Figure given at the Swedish District Heating Workshop)



Simple Power Stations
(Condensing Turbine)

Cogeneration Electricity and District Heating
(Back Pressure Turbine)

FIGURE K-21. SCHEMATICS OF S SIMPLE POWER STATION AND A COGENERATION ELECTRICITY AND DISTRICT HEATING SYSTEM

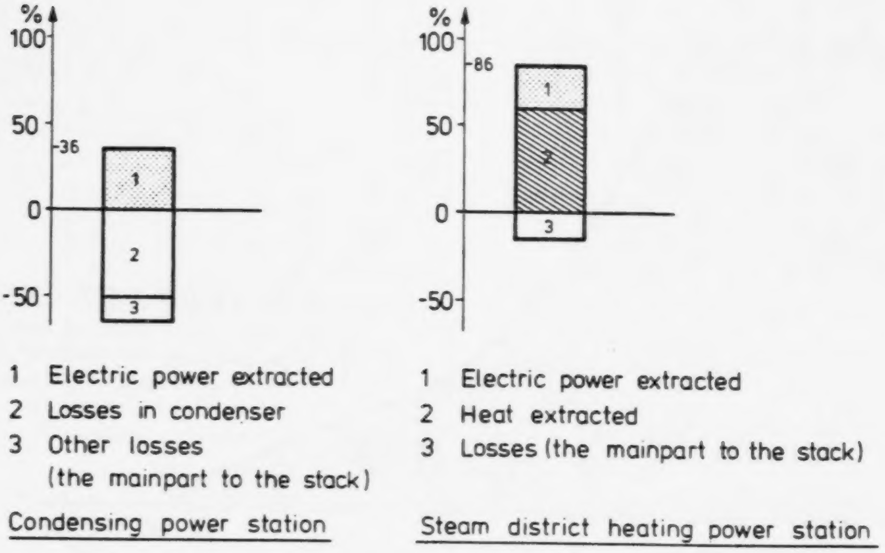
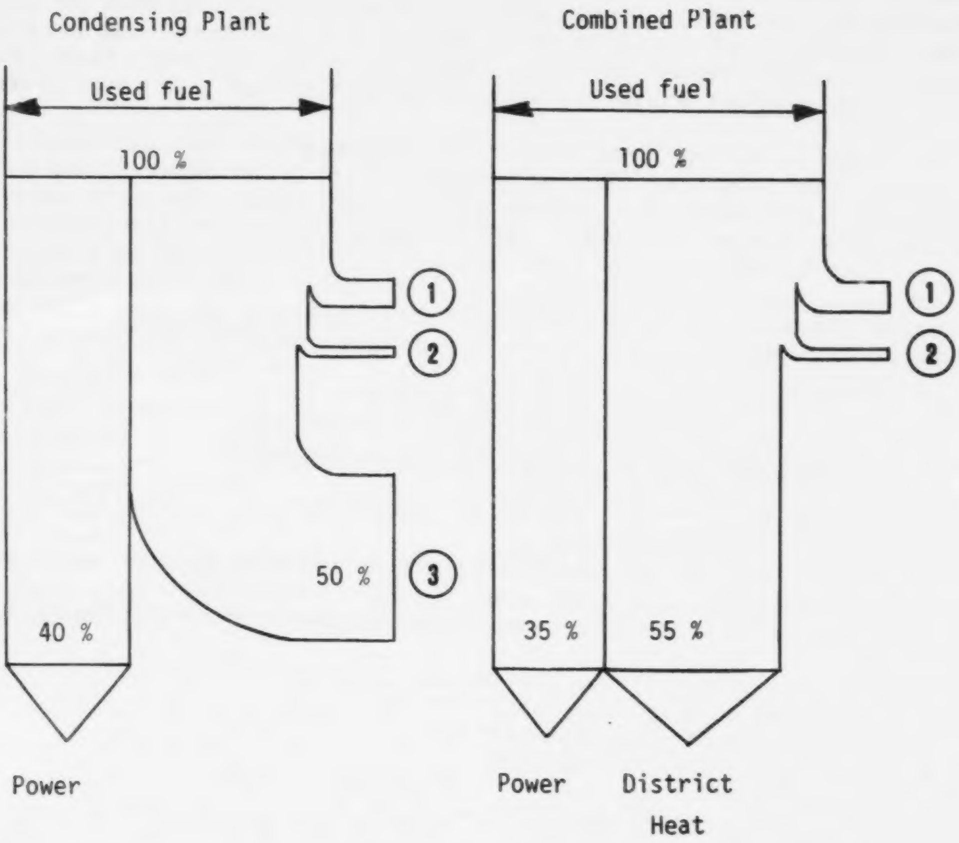


FIGURE K-22. USEFULL ENERGY AND LOSSES OF SIMPLE POWER GENERATION COMPARED WITH COGENERATION

(Courtesy of Jan-Olof Djaru AB Energi Konsult at the Swedish District Heating Workshop)


Condensing Plant
Used fuel
100 %
①
②
③
50 %
40 %
Power
Combined Plant
Used fuel
100 %
①
②
35 %
55 %
Power
District Heat

① = Boiler losses = 8 %
② = Auxiliaries losses = 2 %
③ = Condensor losses

FIGURE K-23. FUEL ECONOMY IN CONDENSING PLANT AND COMBINED PLANT

(Courtesy of Carl-Erik Lind, Head of Energy Section National Board of Industry, Stockholm and the Swedish District Heating Workshop) to 35 percent of the fuel's energy content), condenser losses could be eliminated and the combined efficiency would rise to 85 percent.

Stage 5: Base Load With Distant Nuclear Waste Heat. The Swedes are considering three Stage 4 situation as located in Figure K-24. One of the three would use waste heat from th Forsmark nuclear power station 80 miles North of Stockholm. The refuse fired steam generator plant at Uppsala is part of a larger cogeneration facility in an energy and environmental park as described in the specifc comment section. Thus this refuse derived steam from the Uppsala plant visited would eventually be part "D" of this total energy plan.

On summarizing the five stages, it is important that each stage be developed before future stages are implemented. Any particular stage many require 6 to 12 years before the savings in fuel cost equals the extra expense of installing that stage. Another, perhaps humbling point for resource recovery, is that in the long term refuse-to-energy systems will be a limited factor in the total energy picture. Once again the point is made that resource recovery holds the hope that refuse can be destroyed in an economical and environmentally sound manner. It is not the panacea for the world's energy problems.

Energy Utilization - Specific System Commments

Werdenberg-Liechtenstein

This small 132 ton per day plant produces the most complex assortment of energy forms, considering the plant size, that the researchers have seen in their travels. Figure K-25 shows the components and their interrelationships.

- Hot water for district heating
- Steam for industrial process
- Electricity for the community
- Electricity for internal use
- Steam wasted on the roof
- Steam for internal use
- Hot water for internal use.

When more energy is needed than the refuse fired steam generator (RFSG) can produce, the auxilliary standby oil-fired steam boiler can be used (See Figure K-26).

A back-pressure steam turbine-generator shown in Figure K-27, is used to produce two energy forms: electricity and medium quality steam. A small back-pressure turbo-generator has a maximum electricity generating capacity of 0.85 mw at 10 kv. Inlet pressure is 39 bar (55a psig) (714 F). Outlet pressure is 6 bar (72.5 psig) (1.05 x 10^6 Pa) and temperature is 250 C (482 F). The back pressure varies between 5.5 and 12 bar.

The 250 C, 6 bar exhaust stem from the turbine is cooled to 150 C, 6 bar by direct water spray and is then piped to a nearby chemical plant which returns to condensate at 5 bar with little loss. See Figure K-28 that shows the steam distribution and condensate return tunnel. Excess steam is condensed in a forced draft air-cooled, roof-top conenser. (See Figures K-29a and b.)

Hot water for district heating is produced in a steam-to-hot water

*"D" Includes the Refuse Fired Steam Generator at Uppsala

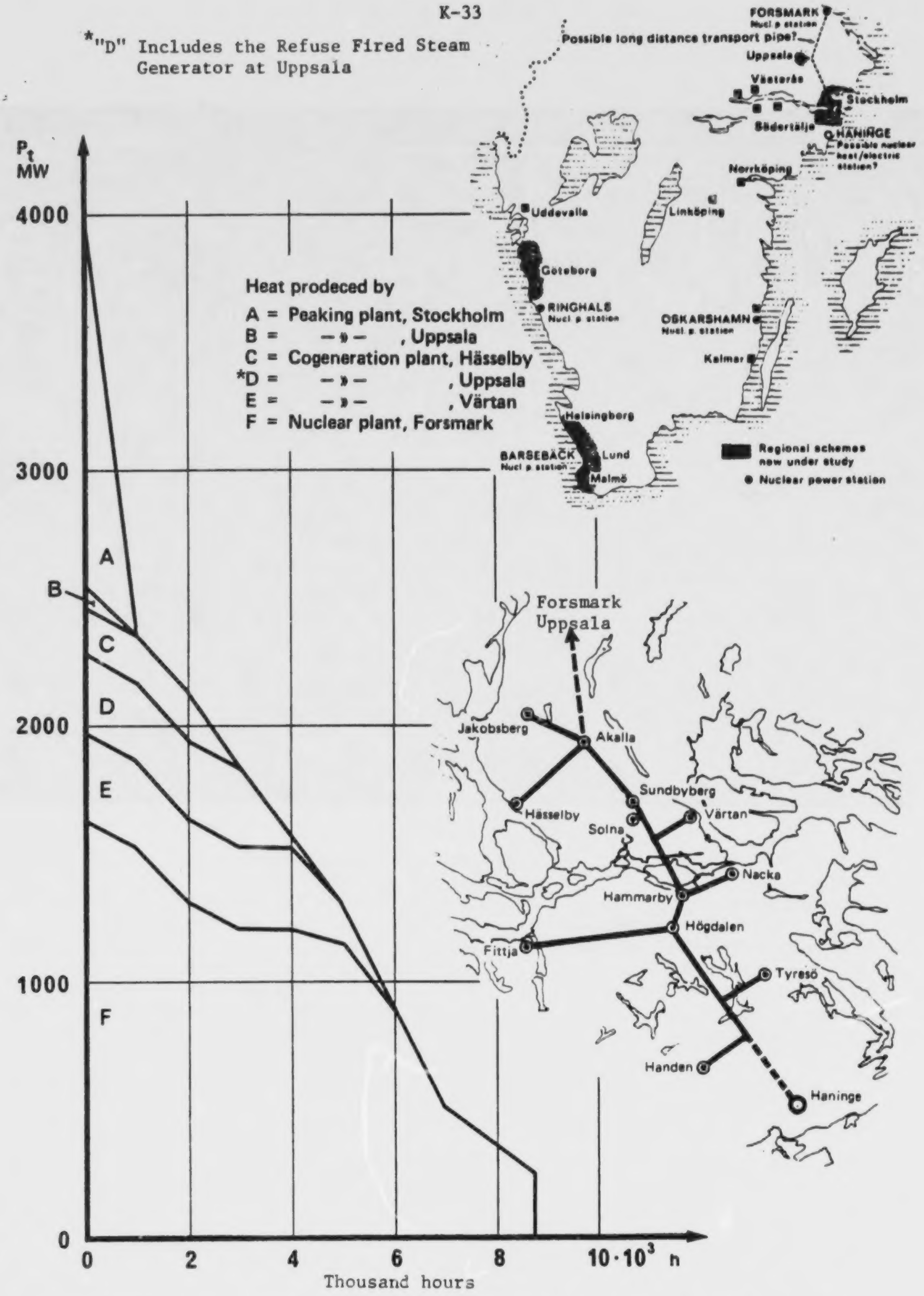
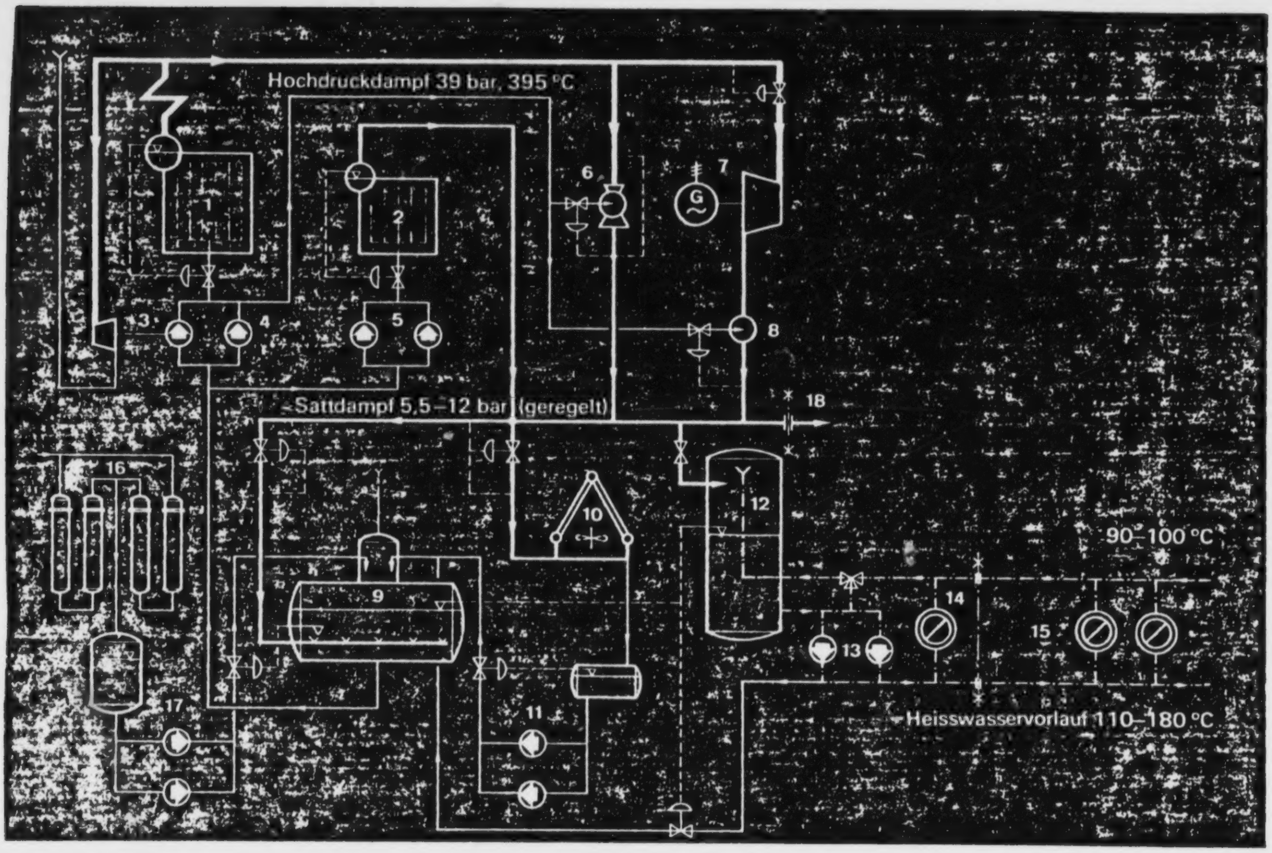


FIGURE K-24. HEAT PRODUCED BY EACH UNIT FOR THE OPTIMUM CASE IN THE LONG RANGE PLAN FOR DISTRICT HEATING SUPPLY IN THE STOCKHOLM AREA USING OIL, REFUSE AND NUCLEAR POWER


Hochdruckdampf 39 bar, 395 °C
1
2
3
4
5
6
7
G
8
Sattdampf 5,5–12 bar (geregelt)
18
16
10
12
9
90–100 °C
14
13
15
17
11
Heisswasservorlauf 110–180 °C

1. Refuse-fired steam generator
2. Oil-fired boiler
3. High-pressure feedwater turbo-pump
4. High-pressure feedwater motorized pump
5. Mid-pressure feedwater motorized pump
6. Turbine steam by-pass
7. Synchronons turbogenerator, 950 Kva
8. Steam temperature regulator
9. Feedwater tank and deaerator
10. Air-cooled condenser
11. Condensate pump
12. Steam-to-water cascade
13. Hot water district heating pump
14. Heat exchange for plant heating
15. District heating system
16. Feedwater treatment facility
17. Makeup water tank and pumps
18. Industry steam supply line

FIGURE K-25. WERDENBERG STEAM AND HOT-WATER DISTRIBUTION SYSTEM (COURTESY WIDMER & ERNST, ALBERTI-FONSAR)

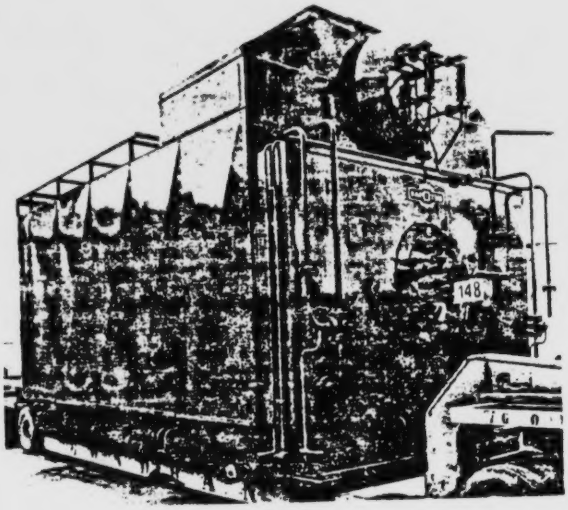


FIGURE K-26. STANDBY OIL-FIRED PACKAGE BOILER AT WERDENBERG

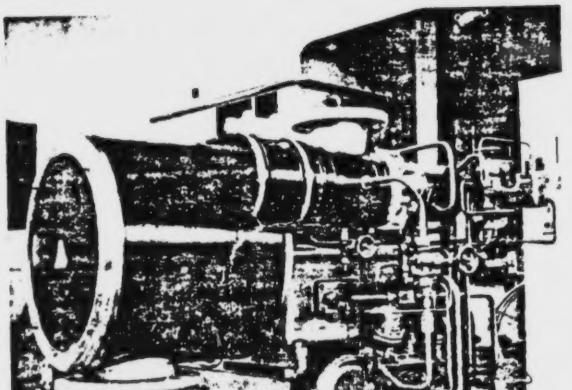


FIGURE K-27. BACK PRESSURE TURBINE AT WERDENBERG

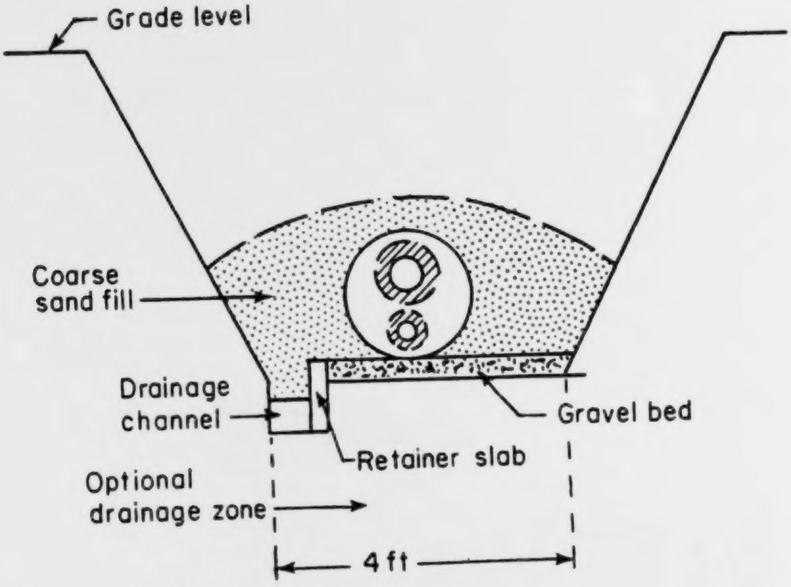
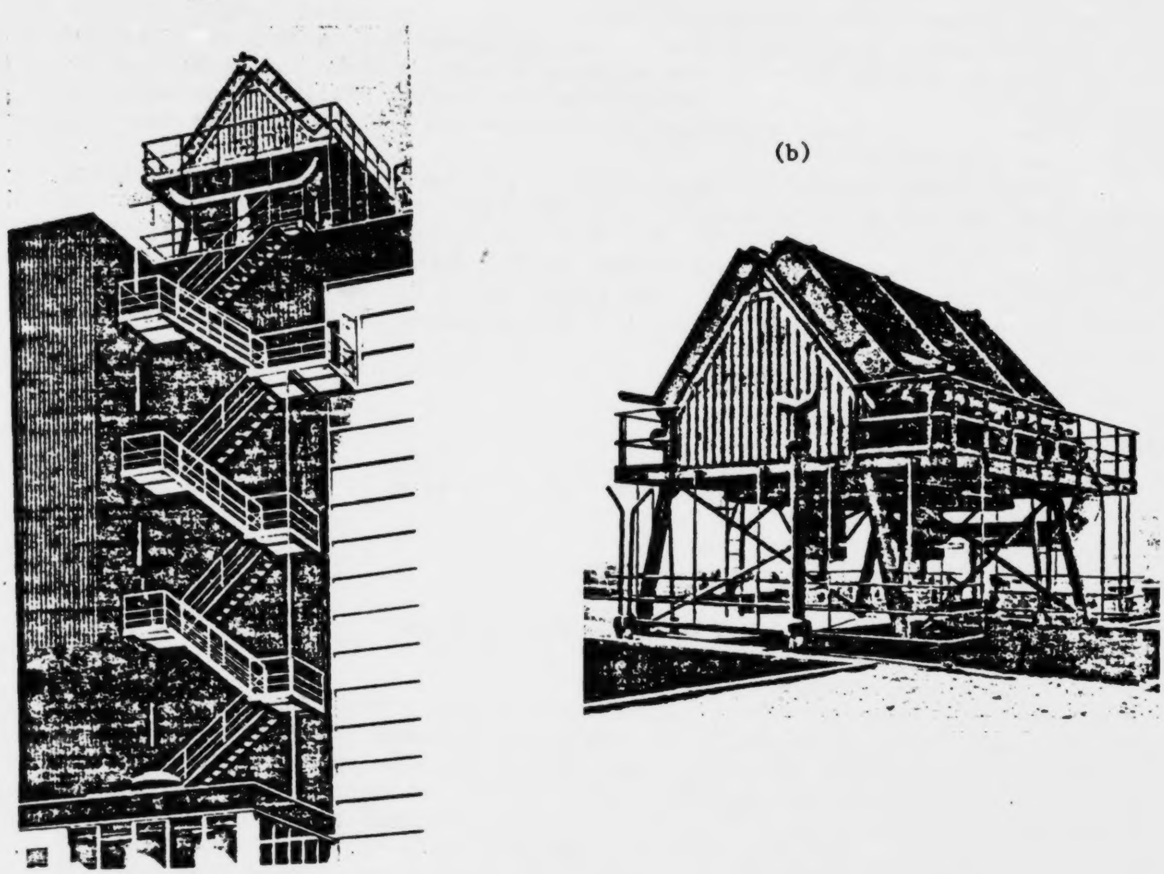

Grade level
Coarse sand fill
Drainage channel
Gravel bed
Retainer slab
Optional drainage zone
4 ft

FIGURE K-28. STEAM DISTRIBUTION TRENCH AT WERDENBERG (COURTESY OF WIDMER & ERNST-ALBERTI-FONSAR)


(a)

(b)

FIGURE K-29. TWO VIEWS OF AIR-COOLED CONDENSER AT WERDENBERG
(COURTESY OF WIDMER & ERNST -ALBERTI-FONSAR)

Hot water for district heating is produced in a steam-to-hot water heat exchanger as seen in Figure K-30. Hot water at 10 bar (130 psig) and a temperature of 100-130 C (212-266 F) is delivered to the same chemical plant and also to an apartment complex involving 300 units. Figures K-31a, b, c, and d show the district heating system under construction, the distribution pattern and the hot water distribution and return line. The total length of the distribution system is 2.5 km (1.5 mi). An additional 0.8 km (0.5 mi) pipeline will be added to provide heat for the railroad station. Other buildings may be included. Where the hot water is utilized for comfort heating, each building has a water-to-water heat exchanger to provide 80 C (176 F) water for the building heating system.

The plant General Manager handles all energy sales. Steam and hot water prices are set so as to compete with the rising cost of fuel oil. At the time of our visit (May 2-3, 1977), No. 2 oil in Switzerland cost approximately 30 SwFr/liter (0.45/gal) or the equivalent of 37 5 SwFr/tonne ($137/ton) ($3.22 per 10^6 Btu) (31.72 SwFr/Gcal). The plant sells hot water at 20 SwFr/Gcal which is 56 percent of the cost of No. 2 fuel oil burned at 90 percent overall efficiency.

Baden-Brugg

The energy export for this plant is as follows:
Electricity to:
1. Sewage treatment plant
2. Aargau Elektriztatswerk (AEW)

Steam to:
1. Fairtec, industrial waste processing plant

Hot water to:
1. Sewage treatment plant.

The electricity is generated in a 6500 KVA Brown-Boveri turbogenerator which consumes a maximum of 25 tonnes/h (55,0900 lb/h) of steam at 40 atm (573 psig) and 400 C (725 F). Its effective ouput is 5.2 MW. The condenser is cooled by river water. This plant has the only water coooled condenser observed at the 15 plants. The condenser is cleaned once every 3 months. Process steam is extracted at 1.5 bar (20 psig) and 205 C (400 F). Heating water is supplied at 70 C to 90 C (160 to 198 F). All of the condensate is returned from the wate processing plant.

They plan to dismantle and reblade the turbine to achieve increased power output from a higher rate in the 1977 summer.

Figure K-32 shows the scheme for heat and electricity distribution.

A long range plan described the possibilities for using turbine exhaust steam for district heating in Baden, possibly tied in with waste heat from a future nuclear plant.

The sewage plant receives electricity at the rate of 19,500 to 32,000 kwhr per week.

The electricity sold to the local network, AEW, produces a variable revenue depending on time of dy and depending on how much hydropower is available to the network. In the winter hydropower is reduced because the highland snowfall does not melt. In the summer Switzerland, as a whole, has excess hydropower and exports electricity. The range of rates paid to the Baden-Brugg plant as follows:

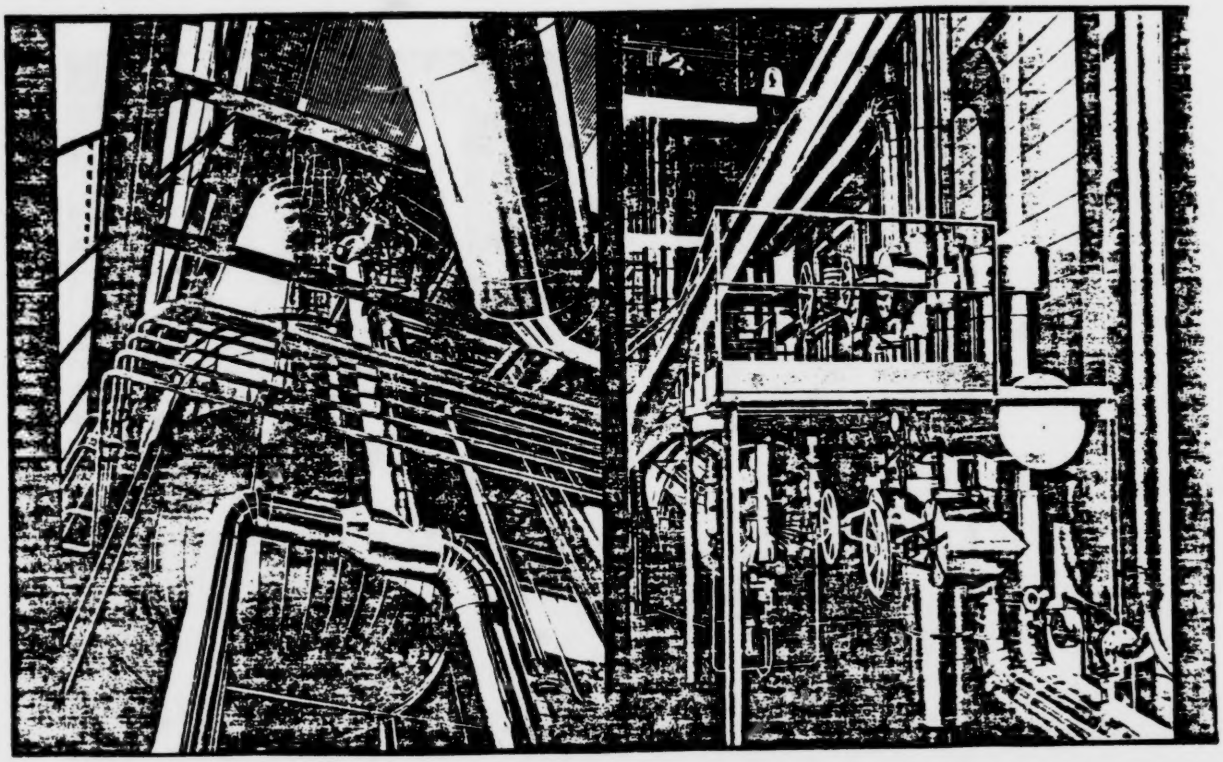


FIGURE K-30. CASCADE TYPE WATER HEATER ON LEFT, FEEDWATER TANK AND STEAM LINES ON RIGHT AT WERDENBERG (COURTESY OF WIDMER & ERNST-ALBERTI-FONSAR)

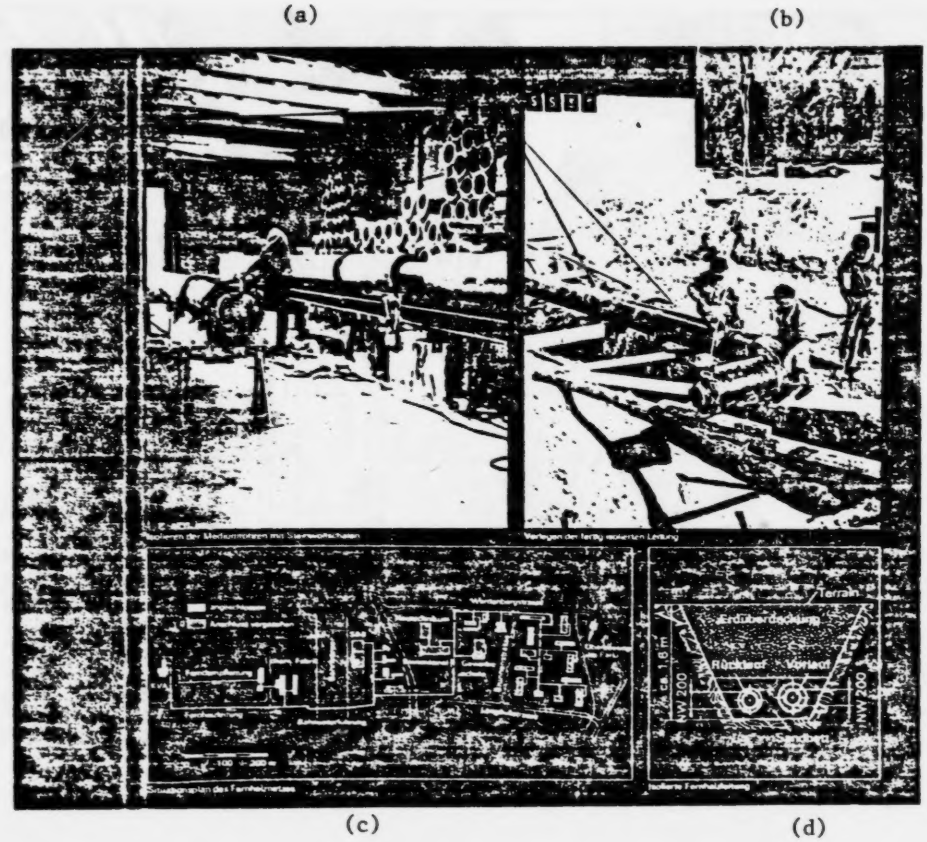

(a)
(b)
Isolieren der Mediumrohren mit Steinwollschalen
Verlegen der fertig isolierten Leitung
Werdenbergstrasse
KVA
-100 0 100 200 m
Situationsplan des Fernheiznetzes
Terrain
Erdüberdeckung
Rücklauf
Vorlauf
ca. 1.8 m
NW 200
NW 200
Sandbett
Isolierte Fernheizleitung
(c)
(d)

FIGURE K-31 INSULATION, INSTALLATION AND MAP OF HOT WATER DISTRIBUTION SYSTEM AT WERDENBERG (Courtesy of Buchswerdenberg Society for Waste Management)

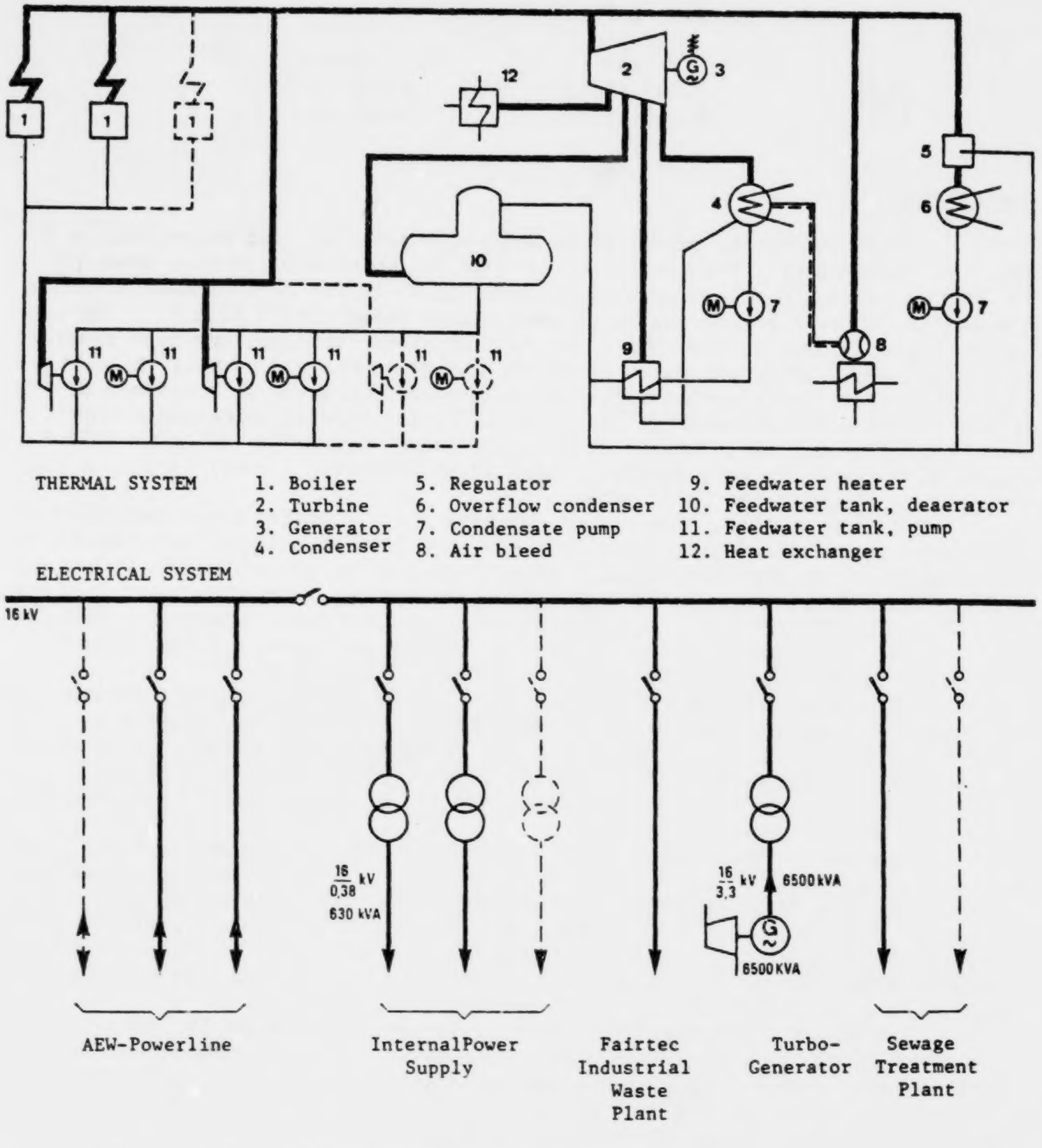

1
1
1
2
3
12
4
5
6
10
7
7
8
9
11
11
11
11
11
11
M
G
THERMAL SYSTEM
1. Boiler
2. Turbine
3. Generator
4. Condenser
5. Regulator
6. Overflow condenser
7. Condensate pump
8. Air bleed
9. Feedwater heater
10. Feedwater tank, deaerator
11. Feedwater tank, pump
12. Heat exchanger
ELECTRICAL SYSTEM
16 kV
16/0,38 kV
630 kVA
16/3,3 kV
6500 kVA
6500 KVA
AEW-Powerline
InternalPower Supply
Fairtec Industrial Waste Plant
Turbo-Generator
Sewage Treatment Plant

FIGURE K-32. SCHEMATIC DIAGRAM OF BADEN-BRUGG THERMAL AND ELECTRICAL SYSTEMS (COURTESY OF WIDMER & ERNST)

S.Fr. per kwhr (US cents/kwhr);

	Winter	Summer
High	0.045 (1.8)	0.030 (1.2)
Low	0.028 (1.1)	0.018 (0.7)

Duesseldorf

This refuse to energy plant was built adjacent, and connected, to the Flingern power plant. The entire output from the burning of refuse goes 700 m (2,30 ft) to the turbines at the Flingern plant in the form of high pressure, 104 bar (1,500 psig or 104 atm) high temperature steam, 500 C (932 F). Here it is utilized in two double shaft condensing steam turbines, one high pressure generating about 32 Mw and a low pressure one generating about 11 Mw. Steam extracted from these turbines is used to produce hot water at a maximum of 130 C (266 F) for district heating. Early in 1977, the Federal government revised regulations permitting hotter district heating hot water at 180 C (356 F). Figure K-33 shows the well insulated pipe (with expansion loops) carrying high temperature steam to the power plant.

In the summer, the refuse-burning plant supplies practically all of the energy needed for district heating. On days with an outdoor temperature of 20 C (68 F), the district supply water temperature is 80 C (176 F) and the system return temperature is 65 C (149 F). The system water flow rate is then 800 m^3/hr (3,520 gpm). In the winter at an outdoor temperature of - 10 C (14 F), flow rate is 1,400 m^3/hr (6,160 gpm) at supply and return temperatures of 130 C (266 F) and 70 C (158 F).

The district heating loop is 15,9 km (10 mi) long and serves 133 buildings included in which are 8,000 apartments. The peak heat demand is 1.97 Gcal/hr (8.25 GJ/hr or 7.82 MBtu/hr). For comparison, the maximum rated output of the five boilers at the refuse burning plant is 110 tonnes/hr (121 tons/hr). However, this full capacity, 963,600 tonnes per year, has never been available for a full year's time.

In 1975, this plant burned 297,359 tonnes of refuse (327,095 tons) and delivered 560,002 tonnes (617,570 tons) of steam (1.89 ton steam/ton refuse) to the Flingern Power Plant, which is 58.1 percent of full rated capacity. The income for this output was 8,125,629.02 DM ($3,412,764.20) or a rate of 14.5 D.M./tonne ($5.53/ton) or $2.76/1,000 lb (approximately $2.76/million Btu). In addition, some steam is used internaly for turbine-drive feedwater and condenser cooling water pumps.

Although the refuse plant does no marketing because it has only one customer, Stadtwerke Elektrizitat, the latter does advertise and has an appliance sales outlet. Aside from selling electricity it also sells district heating hot water and gas. There are 50 people in its salesforce. The Stadtwerke Elekrizitat was converted to a stock company in 1973.

In the district heating system the customer is billed annually but pays on a monthly budget plan. The contract for heating is reviewed annually. The rate is reduced if the customer helps reduce peak demands by installing a heated rock heat storage tank.

The distric heating loop to Garath, a new housing area, was installed and paid for by Stadtwerke Duesseldorf. The loop for the new Duesseldorf University cost DM 10 million ($4.2 million).

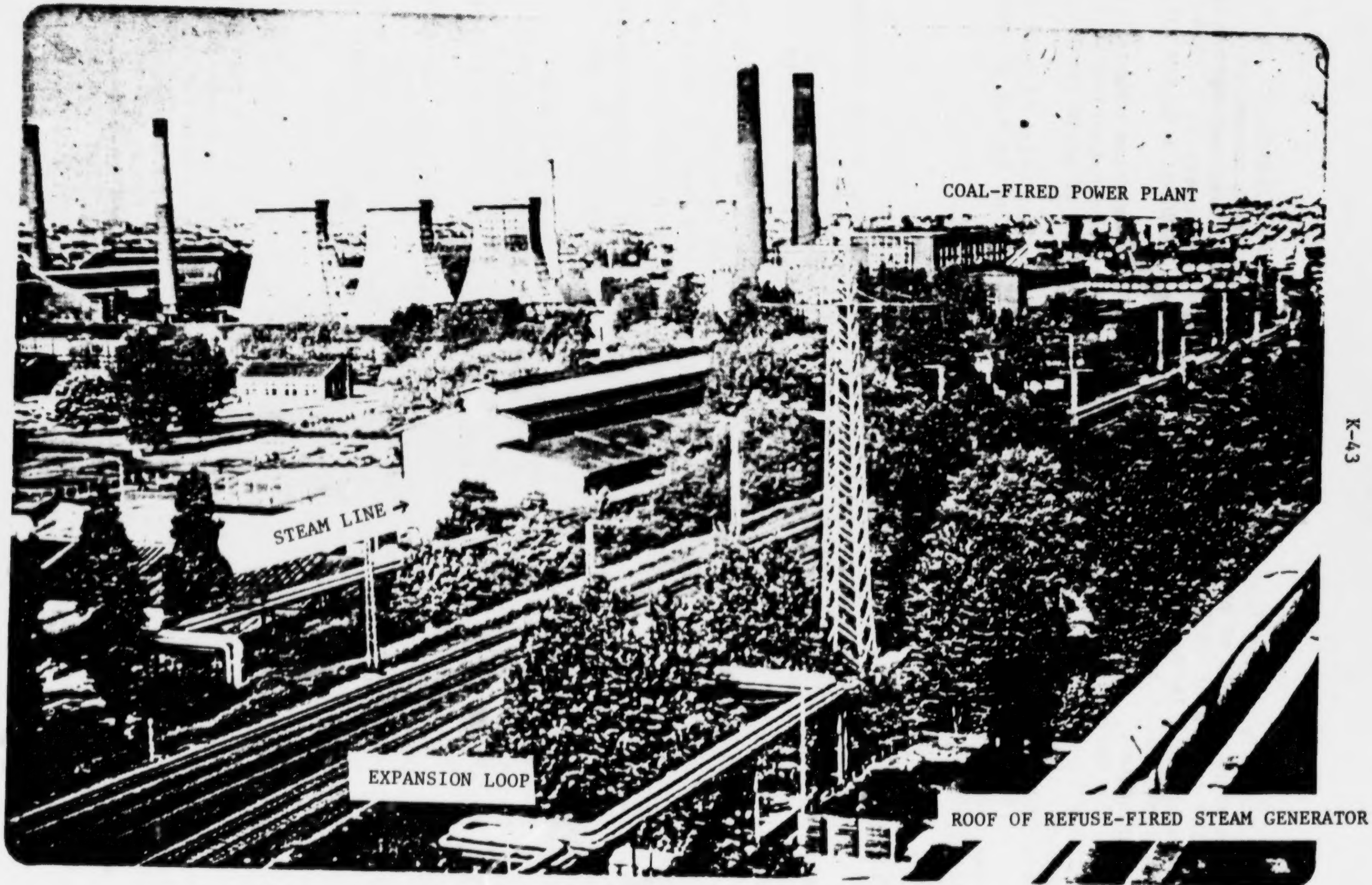

COAL-FIRED POWER PLANT
STEAM LINE →
EXPANSION LOOP
ROOF OF REFUSE-FIRED STEAM GENERATOR

FIGURE K-33. STEAM AND RETURN CONDENSATE LINES CONNECTING DUESSELDORF'S REFUSE-FIRED STEAM GENERATOR AND THE COAL-FIRED ELECTRICAL POWER PLANT

Wuppertal

The only use of the steam generated is to make electricity in two turbo-generators capable of producing 20 mw each. Maximum steam consumption of each is 107 tonnes/hr (235,400 lb/hr). Specific design steam consumption if 5.35 kg/kw-hr (11.8 lb/kw-hr). Exhaust to air-cooled condensers is 0.12 bar (0.12 kg/cm^2) (1.74 psig). The output is supplied at 10,000 volts to the city electrical system.

The condensate returns from the condenser at an average temperature of 52 C (126 F). In order to heat it to 110 C (230 F) before returning it to the boiler, it is mixed with about 10 t/h (22,000 lb/hr) of steam extracted from the turbines.

The only energy sold from this plant is electricity which is sold to the local public power network at a price ranging from 2.6 pf to 4.9 pf/kwhr (0.011 to $0.022 per week).

Krefeld

In addition to the utilization of thermal energy for drying of sewage sludge, some of the energy released in the burning of refuse and that dried sludge is sent as hot water at 130 C (266 F), 10 bar (145 psia) to a railroad car plant located 2.5 km (1.5 mi) away. The water return temperature is 70 C (158 F) at 7 bar (100 psia).

Steam is used for preheating the primary combustion air to 200 C (392 F). Each of two preheaters, made by Duerr, uses 6500 kg/h (14,300 lb/h) saturated steam at 25 bar (363 psia), 225 C (437 F). The heating capacity is 2.816 Gcal/h (11.79 MJ/h) (11,175 Btu/h) when heating air at the rate of 50,000 Nm^3/h (29,425 scfm).

More steam is used internally for one Lugar flue gas reheater following the scrubbers. Using 3,150 kg/h (6930 lb/h) of steam at 22 bar (320 psia) and 375 C (707 F) to 90 C (194 F).

Relatively little energy remains to drive two turbo generators, built by SEG, having a generating capacity of 1.4 Mw each at 10 kv. Each turbine can utlize 17.5 tonnes/h (38,500 lb/h). The design steam outlet conditions are 3.7 bar (53.7 psia) and 206 C (403 F). Any excess steam goes to an air-cooled condenser.

Most of the electricity generated is used internally. Any excess goes to the local network without payment.

The energy sold to the local railroad car plant is the only energy sold because most of the released energy is used internally for primary air heating, sludge drying, electric motors, flue gas reheating.

Paris: Issy

The Paris: Issy plant has both a back presure and a condensing turbine. Steam leaving the superheater enters either one and both produce electricity. The steam leaving the backpressure turbine is used for district heating.

Referring to steam numbers as presented in Table K-9 note that 964,718 tonnes (1,061,190 tons) of steam were produced in 1976. Steam condition was specified at 50 bars (735 psi) and 410 C (770 F). After the

TABLE K-9. STEAM PRODUCTION, LOSSES, SALE AND AVAILABILITY

(Tonnes of Steam)	Month of December		Year of	
	1976	1975	1976	1975
Basic production of steam exiting boilers (50 bars, 410°C)	86,772	81,294	964,718	940,377
Loss at pressure relief valve	(1,026)	--	(14,598)	(3,503)
Technical sampling and losses	(3,256)	(4,077)	(38,580)	(43,172)
Available from boiler	82,490	77,217	911,540	893,702
Condensing turbines	(11,609)	(3,879)	(129,435)	(113,623)
Auxiliary condenser	(72)	--	(1,238)	(538)
Losses to atmosphere	--	(338)	(437)	(660)
Other losses	(614)	(2,380)	(6,241)	(35,082)
Sales to C.P.C.U.(1) for district heating	70,195	70,620	786,671	743,799
Average hourly vaporization during operation	33.2	29.5	33.2	31.9
Hours available of equipment to produce steam	2,880	2,875	30,567	30,348
Boiler availability	96.7	96.6	87.0	86.6
Percent utilization if boiler is available	75.3	70.7	78.9	77.5
Tonnes of steam per tonne of refuse	1.62	1.69	1.67	1.67

Source: TIRU Statistics.

(1) C.P.C.U. is the City of Paris Urban Heating Company.

TABLE K-9. (Continued)

(Mega watt-hours)	Month of December 1976	Month of December 1975	Year of 1976	Year of 1975
Production from counterpressure turbines	3,960	3,576	43,597	42,418
Production from condensing turbine	2,041	696	23,826	20,157
Total production	6,001	4,272	67,423	62,575
Purchase from C.I.M.E.	61	0	300	219
Total available	6,062	4,272	67,723	62,794
Internal uses of electricity	(1,752)	(1,608)	(19,654)	(18,753)
Electricity sale to C.I.M.E.	4,310	2,664	48,069	44,041
Internal consumption (Mw-h) of electricity per tonne of refuse burned	0.032	0.033	0.033	0.033
Counterpressure turbine actual hours	679	744	8,382	8,531
Condensing turbine actual hours	534	219	5,033	4,016
Counterpressure turbine hours available	744	744	8,602	8,613
Condensing turbine hours available	744	510	8,602	7,961
Counterpressure turbine availability	100	100	97.9	98.3
Condensing turbine availability	100	68.6	97.9	90.9
Counterpressure turbine utilization during availability	59.1	53.4	56.3	54.7
Condensing turbine utilization during availability	17.3	8.6	17.4	15.9
Production of electricity (Kw-h) per tonne of steam entering the:				
Counterpressure turbine	48.0	46.3	47.8	47.5
Condensing turbine	175.8	179.4	184.0	177.4

Source: TIRU Statistics.

pressure relief valve and other losses, 911,540 tonnes (1,002,694 tons) remained for constructive uses.

Electricty Generation. Table K-10 shows the five year history of electricity production sales, purchases and internal consumption.

TABLE K-10. HISTORY OF ELECTRICAL PRODDUCTION, SALES, PURCHASES AND INTERNAL CONSUMPTION (MW-HOURS)

	1972	1973	1974	1975	1976
Production	89,633	83,655	72,903	62,575	67,423
Purchases from C.I.M.E.	153	121	491	219	300
Internal Consumption	18,935	19,866	19,780	18,753	19,654
Sales to C.I.M.E.	70,851	63,910	63,910	54,614	49,069

Perhaps for street lighting, the Issy plant purchased 300 Mw-hr from the other E.D.F. Subsidiary for distribution: C.I.M.E. This gives a gross 67,723 Mw-hr. Interestingly 29 percent of the electrical production (19,654 Mw-hr) was used internally. This left 48,069 Mw-hr for sale back to C.I.M.E. Internal consumption of electricity was 0.033 Mw-hr per tonne of refuse burned.

Operating results from the two turbines are summarized below.

Backpressure Turbine-Generator. The counterpressure turbine-generator set is rated at 9 Mw.

The unit produced 43,597 Mw-hr in 1976 or 2/3 of Issy's output, an increase of 2.8 percent over 1975. Steam flowed through the unit for 8,382 hours but was available for 8,602 hours out of a possible 8,874 hours. The availability was thus 97.9 percent.

Because electricity was not always required, the generator was used only 56.3 percent of the time. The unit produced 47.8 kw-hr of electricity per tonne of steam entering the turbine.

Condensing Turbine (Low Pressure). The other turbine is a low pressure condensing turbine-generator set is rated at 16 Mw. This unit, while rated higher, only produced 1/3 of Issy's output. This was 18.2 percent higher than in 1975. Steam flowed through the unit for 5,033 hours but was available for 8,602 hours out of a possible 8,782 hours. The availability was thus 97.6 percent.

Because the condensing turbine can supply little or no energy for the more profitable district heating uses, this large and more efficient generator was used only 17.4 percent of the time. The unit produced 184.0 kw-hr of electricity per tonne of steam entering the turbine.

C.P.C.U. District Heating Steam Inputs. To properly understand Issy, it is important to understand the total steam inputs to Issy's major steam (not electric) customer, The City of Paris Urban Heating Company (C.P.U.H.). C.P.U.H. is the single distributor of district heating steam regardless of the fuel.

- C.P.C.U., also uses fossil fuel to produce steam. C.P.C.U. is a subsidiary of electricitie de France (E.D.F.).
- The Electricitie De France (E.D.F.) power plant, which closed in 1973, once supplied a minor amount of steam to the network.
- Industrial Treatment of Urban Waste (T.I.R.U.), a subsidiary of E.D.F., currently produces steam flow refuse.

Table K-11a, shows the maximum hourly capacity of the key organization contributors, climatological data and actual annual production.

All three T.I.R.U. refuse-fired plants only account for 29 to 33 percent of total C.P.C.U. demand. Issy, in 1975, produced only 12..3 percent of the total C.P.C.U. requirements.

The 5-year history describing the growth of the C.P.C.U. district heating network is portrayed in Table K-12. C.P.C.U.'s growth in demand was about 10 percent per year until the oil crisis. Their own oil-fired plants then became less competitive. Customers in new buildings returned to consideration of small electric or gasfired heating systems.

By 1975, 3,208 buildings were receiving steam. Slightly over a third of the energy goes to residences and a third to offices as seen in Table K-13.

In December 31, 1975, the trunk line was 196 km (118 miles) long while the branch lines were only 29 km (17 miles) long for a grand total of 225 km (135 miles). The heat density has been gradually rising up to 13.1 kilotherms per hour per kilometer of pipe. The return condensate percent averages about 91 percent.

The steam is distributed in insulated pipes. The return condensate pipe is in the same tunnel as shown in Figure K-34.

The monthly pattern shown in Figure K-35 clearly shows that all three of the T.I.R.U. rfuse fired plants provide the base load. Only during the August vacation period does the T.I.R.U. production fall to 90,000 tonnes (99,000 tons) per month compared to 210,000 tonnes (231,000 tons) in January. The fossil fuel C.P.C.U. steam production plants are clearly peak loading plants.

Hamburg:Stellinger-Moor

Electricity for the network and steam for internal uses are the energy products from Hamburg's plant located in Stelligen. Martin's analog computer controls the observed steam temperature of 400 C (752 F) to within two degrees. The pressure is equally as steady at 40 Kg/cm^2 (588 psi).

Turbines. Two topping-off condensing turbines each have steam consumption capacities of 88 tonnes (97 tons) steam/hour. However, one is a spare and the running turbine usually consumes only 60 tonnes (65 tons) steam/hour.

Table K-14 shows (among many other numbers that the total steam consumed per year was essesntially constant. However, in 1975, Turbine 1

TABLE K-11. C.P.C.U. DISTRICT HEATING USES, PRODUCTION CAPACITY, CLIMATOLOGICAL CONDITIONS AND ANNUAL ACTUAL STEAM PRODUCTION

(a)

	Hourly Installed Capacity (Tonnes/Hour)				
	1971	1972	1973	1974	1975
C.P.C.U. (Fossil Fuel)	1,690	1,840	1,870	2,470	2,510
E.D.F. (Steam from Old Power Plant)	300	300	300	--	--
T.I.R.U. (Refuse)	245	245	280	295	295
Production Capacity (Tonnes/Hour)	2,235	2,385	2,450	2,765	2,805

(b)

	Climatological Conditions				
	1971	1972	1973	1974	1975
Average 7-Month Heating Season					
Temperature °C	7.38	7.82	6.92	8.42	7.39
Degree Days	2252	2168	2349	2031	2250

(c)

	Annual Actual Production Used by C.P.C.U. for District Heating (Thousand Tonnes/Year)					
	1971	1972	1973	1974	1975	1976
C.P.C.U. (Fossil Fuel)	2,963	3,957	4,095	3,697	4,029	
E.D.F. (Closed)	306	97	240	224	--	--
Issy (Refuse)	↑	603	653	644	744	787
Ivry (Refuse)	1,670	639	767	784	852	767
Saint-Ouen (Refuse)	↓	411	392	403	415	404
Inconsistencies	0	3	2	(3)	0	
Actual Steam Production	4,939	5,710	6,149	5,747	6,040	

TABLE K-12. C.P.C.U DISTRICT HEATING NETWORK FACTS

	1971	1972	1973	1974	1975	1976
Trunk Pipe Line Distance (Km)	167	174	181	193	196	
Branch Pipe Line Distance (Km)	22	23	25	27	29	
TOTAL Network Pipeline Distance (Km)	189	197	206	220	225	
Pipeline Heat Density (Kth/hr/Km)	10.7	11.3	11.9	12.4	13.1	
Return Condensate (Percent)	91.4	90.2	91.1	90.5	91.2	
Number of Buildings	2,526	2,703	2,878	3,029	3,208	
Energy Delivered (Kth/hr)	1,794	1,970	2,162	2,400	2,561	

TABLE K-13. C.P.C.U. PERCENT DISTRIBUTION OF CUSTOMERS

	1971	1972	1973	1974	1975	1976
Residences	28.3	30.8	32.5	33.5	34.6	
Hotels, Cafes, Restaurants	3.4	3.4	3.1	3.5	3.4	
Offices	36.9	36.8	37.1	36.3	35.5	
Hospitals, Clinics, Nurseries	7.7	7.1	6.9	7.8	7.4	
Schools, Universities, Churches	14.8	13.8	12.9	11.7	11.8	
Miscellaneous	8.9	8.1	7.5	7.2	7.3	
	100.0	100.0	100.0	100.0	100.0	

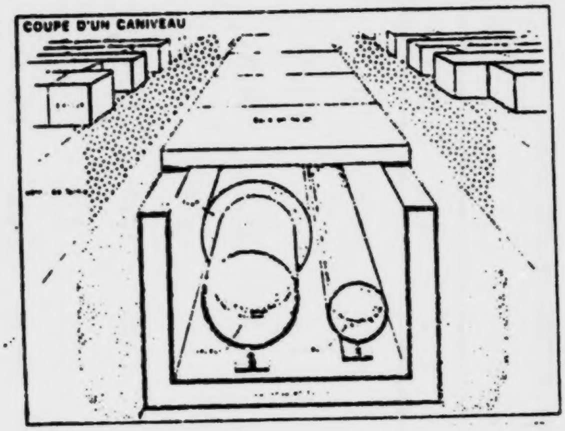

COUPE D'UN CANIVEAU

FIGURE K-34. STEAM DISTRIBUTION AND RETURN CONDENSATE PIPES OF C.P.C.U. IN PARIS

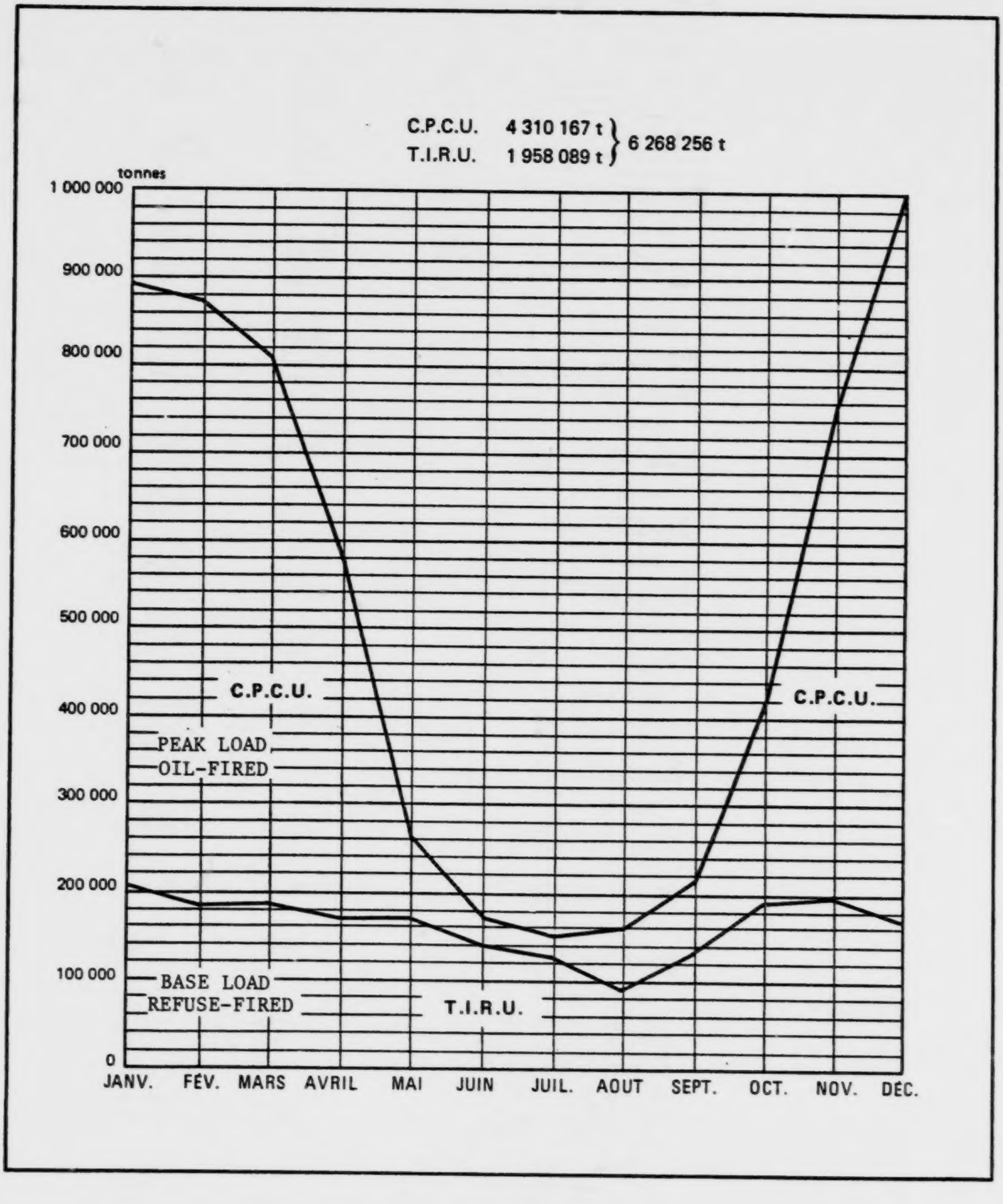


FIGURE K-35. STEAM PRODUCED BY TIRU (SOLIDWASTE FUELED)
AND BY C.P.C.U. (FOSSIL FUELED) IN PARIS

TABLE K-14. HAMBURG: STELLINGER-MOOR TOTAL OPERATING FIGURES

	December 1976	Year 1976	Year 1975
Truck Deliveries			
Household trucks (number)	3,233	38,754	49,686
Industrial trucks (number)	198	3,542	4,488
Total trucks (number)	3,431	42,296	54,174
Waste Input			
Household waste (tonnes)	14,469	161,617	216,848
Industry waste (tonnes)	881	14,899	19,125
Miscellaneous waste (tonnes)	3,487	18,748	2,801
Total waste (tonnes)	18,837	195,264	238,774
Boiler 1			
Waste input (tonnes)	9,535	98,762	118,412
Steam generated (tonnes)	22,391	217,706	231,028
Steam / waste (tonnes / tonnes)	2.35	2.20	1.95
Operating time (hours)	744	7119	7264
Boiler 2			
Waste input (tonnes)	8,640	101,794	115,828
Steam generated (tonnes)	19,888	210,286	226,992
Steam / waste (tonnes / tonnes)	2.30	2.07	1.86
Operating time (hours)	665	7311	7505
Boilers 1 and 2			
Waste input (tonnes)	18,175	200,556	234,240
Steam generated (tonnes)	42,279	427,992	458,020
Steam / waste (tonnes / tonnes)	2.33	2.13	1.96
Operating time (hours)	1409	14430	14769
Fuel Oil #2			
Delivery (liters)	10,016	98,934	83,004
Consumption (liters)	16,940	104,398	83,183
Turbine 1			
Steam consumed (tonnes)	—	110,170	306,258
Operating time (hours)	—	2,187	6,059
Turbine 2			
Steam consumed (tonnes)	41,448	310,505	137,090
Operating time (hours)	744	6,669	2,872
Turbines 1 and 2			
Steam consumed (tonnes)	41,448	420,675	443,348
Operating time (hours)	744	8,856	8,931
Power Supply			
Generator 1 (kwh)	—	19,478,100	55,043,300
Generator 2 (kwh)	6,900,500	49,761,000	23,012,000
Generator total (kwh)	6,900,500	69,239,100	78,055,300
Purchased power (kwh)	--	196,350	209,550
Total power available (kwh)	6,900,500	69,435,450	78,264,850
Power Use			
Sewage treat plant (kwh)	417,582	4,308,709	3,963,977
Internal plant consumption (kwh)	1,295,168	12,228,467	12,492,885
Stavklast-heavy-base (kwh)	1,306,900	13,224,750	15,467,100
Schwuchlast-weak-peak (kwh)	3,875,850	39,616,500	46,333,650
Total power used (kwh)	6,895,400	69,378,426	78,257,612
Water Supply			
Purchase from Hamb. W.W. (m^3)	1,303	15,276	12,394
Well fed cooling water (m^3)	14,938	179,855	177,859
Water Uses			
Consumption of H.W.W. (m^3)	93	1,810	843
Change in stock of H.W.W. (m^3)	--	254	247
Sanitary uses of H.W.W. (m^3)	710	7,582	7,429
H.W.W. to treatment station (m^3)	500	5,884	4,320
Well water to treatment station (m^3)	7,984	78,777	21,031
Well water process water (m^3)	7,054	101,332	157,075
Boiler feedwater addition (m^3)	976	12,179	22,379
Residuals			
Ash for roadbuilding (tonne)	2,316	73,251	80,756
Big scrap iron (tonne)	663	11,737	14,129
Small scrap iron	369	3,837	6,268
Stumps and tires landfilled			
Total recycle residuals (tonne)	3,348	98,825	101,153

Source: Stellinger-Moor plant operations staff T3/R56 Betriebsergebnisse ae. MEA II January 11, 1977.

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carried the load and in 1976, Turbine 2 carried the load. This was due to planned equipment overhaul and planned downtime of a spare turbine.

The maximum generating capacity (assuming that enough steam is available) is "two times 5 Mw or 10 Mw for internal use", as was stated in an interview.

Electricity is sold to the local power grid, Hamburg Electrical Works (HEW). Figure K-36 shows the general electrical network feeding into the 110 KV line of Hew.

Power Generated and Used. Electrical power is generated in the two turbogenerator sets and produced 69,239,100 kwhr in 1976. This had to be augmented with 196,350 kwhr of purchased electricity from the plants major customer.

S-M sells to HEW its electricity for .03 DM or 3 Pf ($0.0125) per kwh but S-M must pay this same Hamburg Electrical Works .40 DM or 40 Pf ($0.1667) per kwh. Multiplying quantity and price for 1976 gives the following results:

Plant Sales	Plant Purchases
52,841,250	196,350
0.03 DM	0.40 DM
1,585,237.50 DM	78,540 DM
$660.515	$32,725

The electrical power is used in the following manner:

		1976
Stauklast - heavy - base	(?)	13,224,750 kwh
Schwuchlast - weak - peak	(?)	39,616,500
Total sold to HEW		52,841,250
Sewage treatment plant		4,308,709
Internal uses		12,228,467 kwh
Total uses of electrical power		69,378,426 kwh

Internal Steam Uses. Steam can be drawn off the turbines at 2.5 bars (36 psi). Such steam has four key uses inside the S-M plant:

- Sootblowing
- Building heating
- Feedwater heating
- Air preheating

Plant people reported that steam is used at the rate of 10 tonnes (11 tons) during the 1/2 minute sootblowing cycle. The rate, while substantial, is only for a short time and is hardly felt at the turbine.

Zurich: Hagenholz

Energy utilization at Zurich:Hagenholz is among the most advanced plants in Europe. Max Baltensperger the administrator repeatedly pointed out that Hagenholz is primarily an energy plant. The plant is integrated with the other conventional fossil fuel district heating and electricity plants. A new oil fired energy plant is located nearby. The total story involves the following energy media:

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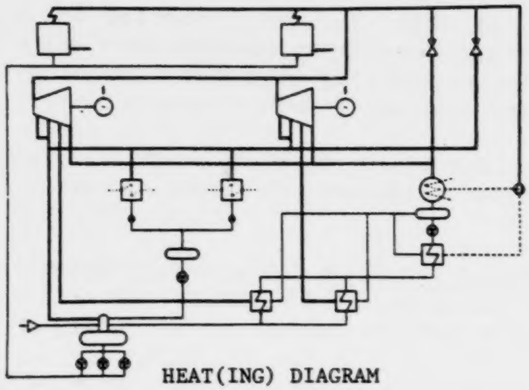
*Using a conversion rate of 2.40 DM/$1.00.



HEAT(ING) DIAGRAM

Wärmeschema

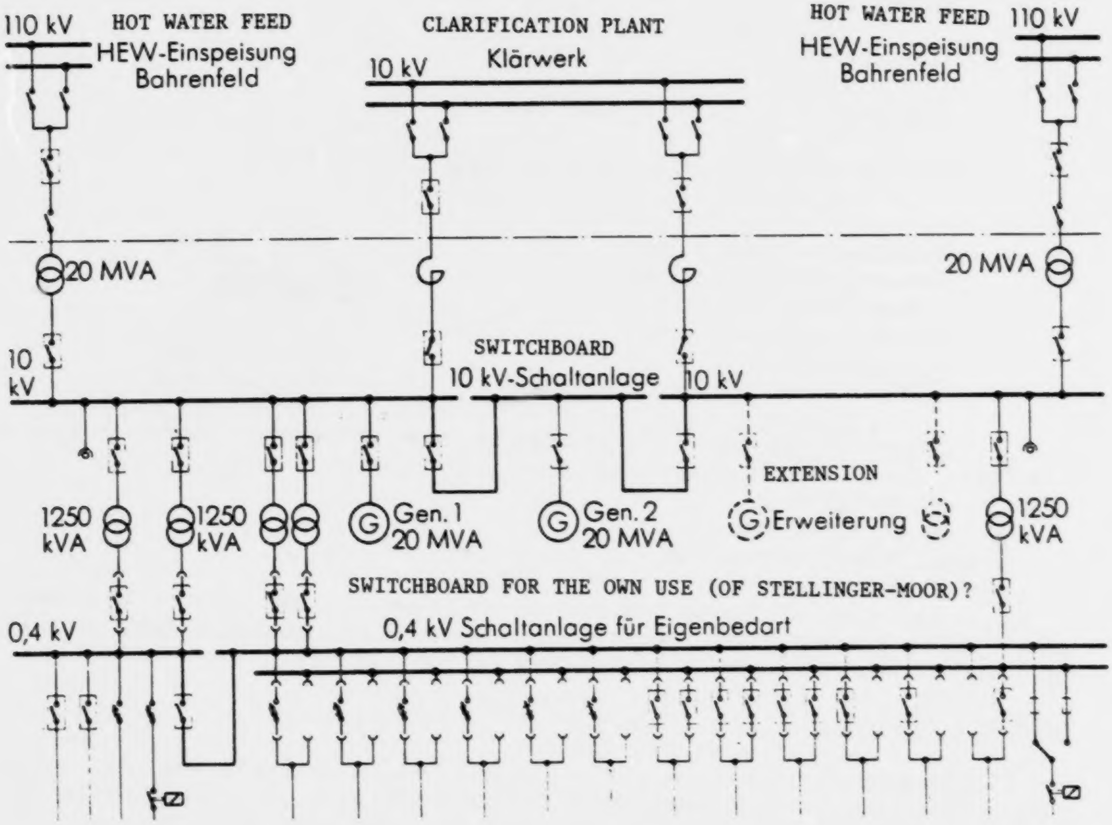

110 kV
HOT WATER FEED
HEW-Einspeisung Bahrenfeld
CLARIFICATION PLANT
10 kV
Klärwerk
HOT WATER FEED
110 kV
HEW-Einspeisung Bahrenfeld
20 MVA
20 MVA
10 kV
SWITCHBOARD
10 kV-Schaltanlage
10 kV
EXTENSION
1250 kVA
1250 kVA
Gen. 1 20 MVA
Gen. 2 20 MVA
Erweiterung
1250 kVA
SWITCHBOARD FOR THE OWN USE (OF STELLINGER-MOOR)?
0,4 kV
0,4 kV Schaltanlage für Eigenbedart

FIGURE K-36. DIAGRAMS THERMAL AND OF ELECTRICAL SYSTEMS AT STELLINGER-MOOR. (Courtesy City of Hamburg)

Hagenholz Refuse Fired Steam Generator.

High temperature steam for electricity production (steam extraction - condensing turbo generators)	420 C (500 F)
Medium temperature steam for district heating (Kanton, the municipal district heating system)	260 C (500 F)
Hot water for district heating (EWZ, the investor-owned public utility for electricity and district heating)	130 C (266 F)
Hot water for a State hospital (sterilizing), small factory in Hagenholz, the railroad station, and perhaps tthe Technical University (5 km/line)	130 C (266 F)
Electricity for the two networks (Kanton and EWZ)	11,000 volts
Electricity for internal use, truck garage, and workshop	220 v and 380 v
High temperature steam for the rendering plant	

New Oil Fired Energy Plant.

Hot water for district heating (Kanton, the municipal owned district heating system)	180 C (356 F)

Figure K-37 shows the electrical power generation room and some of its equipment. The full energy product schematic for the plant is shown on the same page in Figure K-38.

Figure K-39 presents a relatively flat picture of total steam produced per ton of refuse consumed during the 52 week year. The average is 2.41 tonnes of steam produced per one tonne of refuse input.

Figure K-40, showing kwh electrical sales per tonne of refuse consumer, however, does have a substantial seasonal pattern that compliments the district heating pattern. The philosophy is that district heating demand is the first priority.

Electricity Generation. High temperature/pressure steam from all three Hagenholz units is fed into two Escher-Wyss (since acquired by Sulzer of Zurich) steam extraction-condensing turbines. Each consumes 30 tonnes (33 tons) of steam per hour for a total of 60 tonnes (66 tons).

Each then produces 6 Mw for a 12 Mw total at 11,000 volts which is the local network voltage. Actually there are two electricity customers: the Kanton (local government) and EWZ (a public unility). The turbine speed is 6800 rpm. A gear box connects it to the generator having a 3000 rpm speed. There has been very little trouble with the turbogenerator set. Once produced, the voltage can be lowered to 220 v and 380 v for internal use.

The new Josefstrasse plant will be equipped with two 40 tonne steam per hour Brown-Boveri turbo generator sets. Each will produce 8 Mw for a 16 Mw total. There will be no gear box; thus the efficiency will be less but the noise will also be less.

District Heating. The Hagenholz refuse fired plant and the oil fired energy plant provide steam and hot water for three different district heating networks. Most of the district heating piping has been in place for many years.

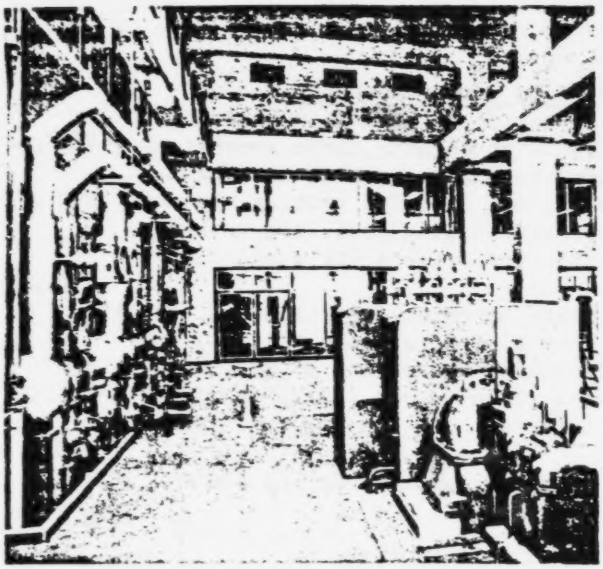
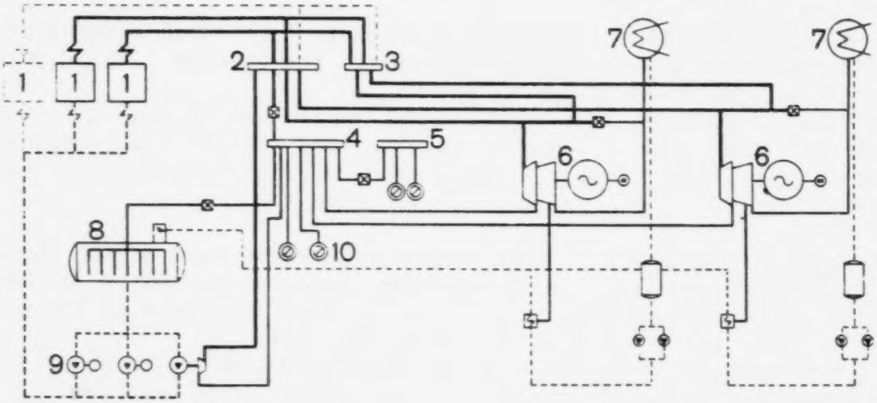


FIGURE K-37. ELECTRICAL POWER GENERATION ROOM



1. Furnace/Boilers
2. High pressure distribution valve
3. Governing valve
4. Medium pressure distribution valve
5. Low pressure distribution valve
6. Turbogenerator
7. Air condenser
8. Feedwater storage and deaerator
9. Feedwater pump
10. Steam for district heating

FIGURE K-38. STEAM AND BOILER FEEDWATER FLOW PATTERN EXTERNAL TO THE ZURICH: HAGENHOLZ BOILER

1976

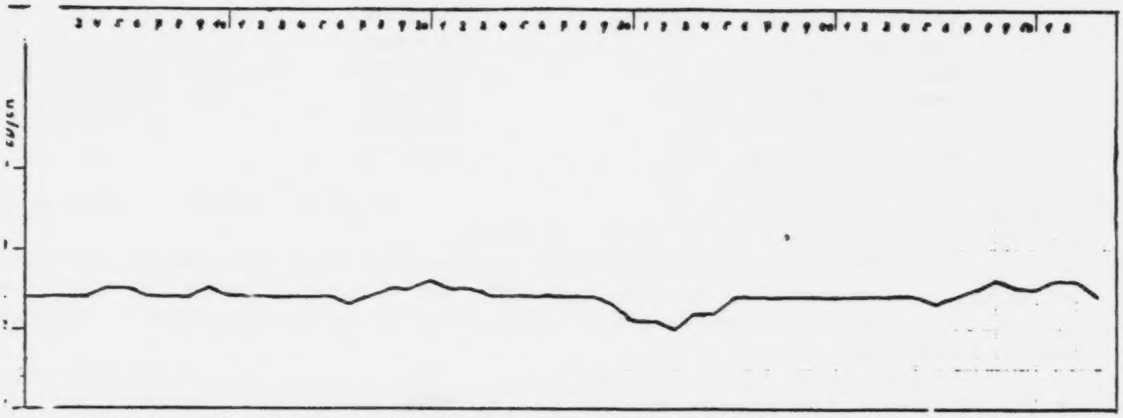


FIGURE K-39. TONNE STEAM PRODUCED PER TONNE OF REFUSE CONSUMER (1976 AVERAGE WAS 2.41)

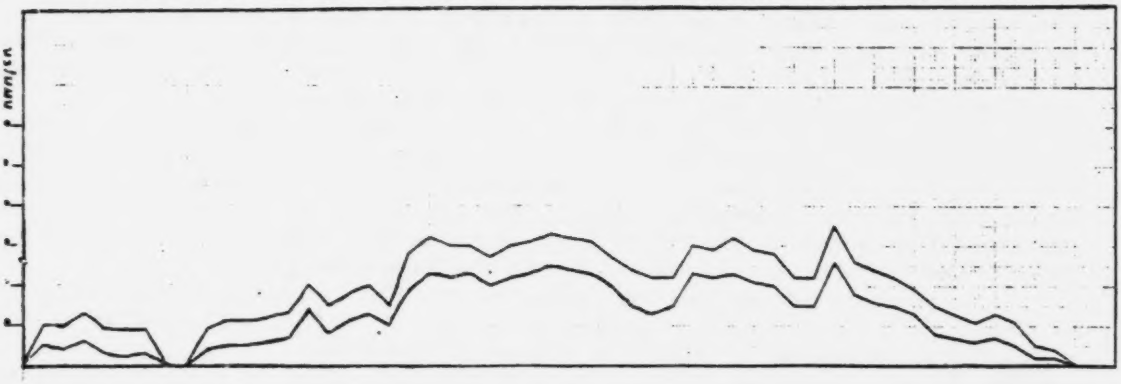


FIGURE K-40. KWH ELECTRICAL SALES PER TONNE OF REFUSE CONSUMED

The investor-owned public utility EWZ plant receives hot water from Hagenholz which is added to the larger EWZ supply. This hot water, at 130 C (266 F), is then distributed to many customers in Zurich. The weekly load is shown in Figure K-41.

The second, a Kanton-owned district heating system, (See the map Figure K-42) has only a few large customers and has a limited potential as listed below:

Kanton municipal hospital	(current)
Ramibuhl factory	(current)
Railroad station	(current)
Post office	(current)
University	(current)
Municipal museum	(current)

This system uses about 15 tonnes (16.5 tons) of steam per hour in the Winter and 10 tonnes (11 tons) per hour in the Summer.

The third district heating system has many apartments and other buildings as customers and is also owned by the Kanton. It is basically the system that the Josefstrasse plant supplied which is now supplied by Hagenholz while Josefstrasse is being rebuilt.

These three district heating networks are supplied by several energy plants. Two of the energy plants are in the Hagenholz suburb; (1) the Hagenholz refuse fired steam generator, and (2) the oil fired energy plant. The supply and return pipelines connecting the two plants with the three networks are in a ground-level, walk-through tunnel covered with earth as shown in Figure K-43. Figure K-44 is a cross-section schematic of the tunnel showing the supply and return lines for water, steam, and condensate.

The purge system for outbound steam pipes is used when the steam is being turned off or being turned on. Pipe number 8 travels the distance of the tunnel collecting condensate from the cooled steam pipe (not to be confused withh the return condensate pipes). The condensate is collected in the purge tanks and then added to the return condensate tanks. One pipe (number 6) then returns the combined liquid condensate to the Hagenholz plant.

The steam and purge line pressures are limited to a slight superheat of 260 C (500 F) and 12 to 14 atmospheres (176 to 205 psi) because of local regulations relating to pipeline expansion problems. The pipe from the condensate return collection tank back to the RFSG plant is at five atmospheres (75 psi) pressure.

The hot water and steam supply and return lines are inspected and reconditioned once per year in the summer.

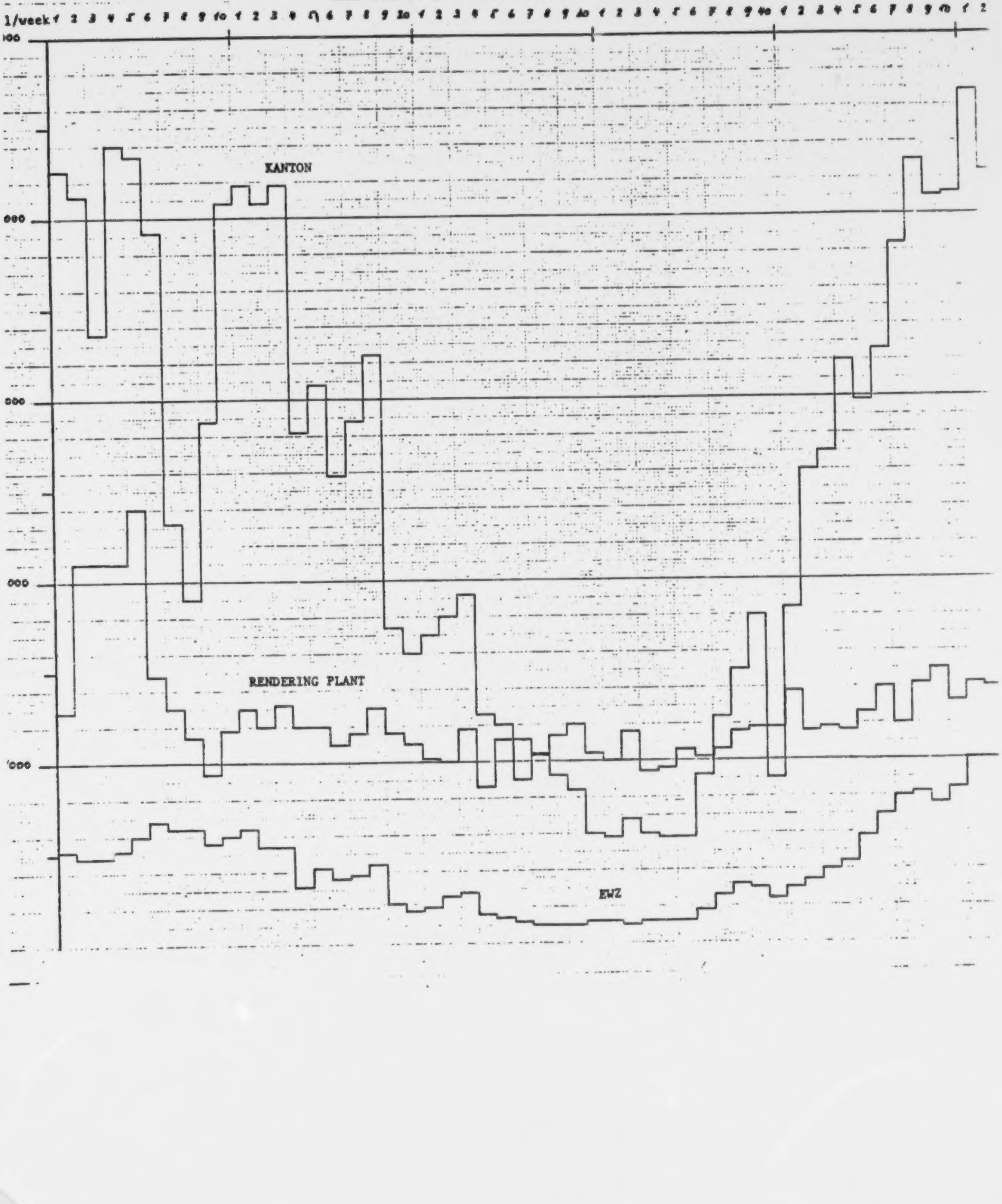
The electricity sells for SF 0.06/kwh ($0.03/kwh) in the Winter and SF 0.04/kwh ($0.02 /kw) in the Summer.

The charge for district heating steam is SF 35 to SF 60/Gcal depending on who the customer is and how much of the pipeline capital cost the customer is paying for.

Figure K-45 shows the weekly pattern of steam sales to the railroad central station (SBB), KZW, and to EWZ.

There has been almost no corrosion of pipes in these walk-through tunnels. The district heating system is stopped once per year for valve reairs were necessary.

FIGURE K-41. 1976 HEAT DELIVERY TO KANTON AND RENDERING PLANT AND STEAM TO EWZ FROM ZURICH:HAGENHOLZ



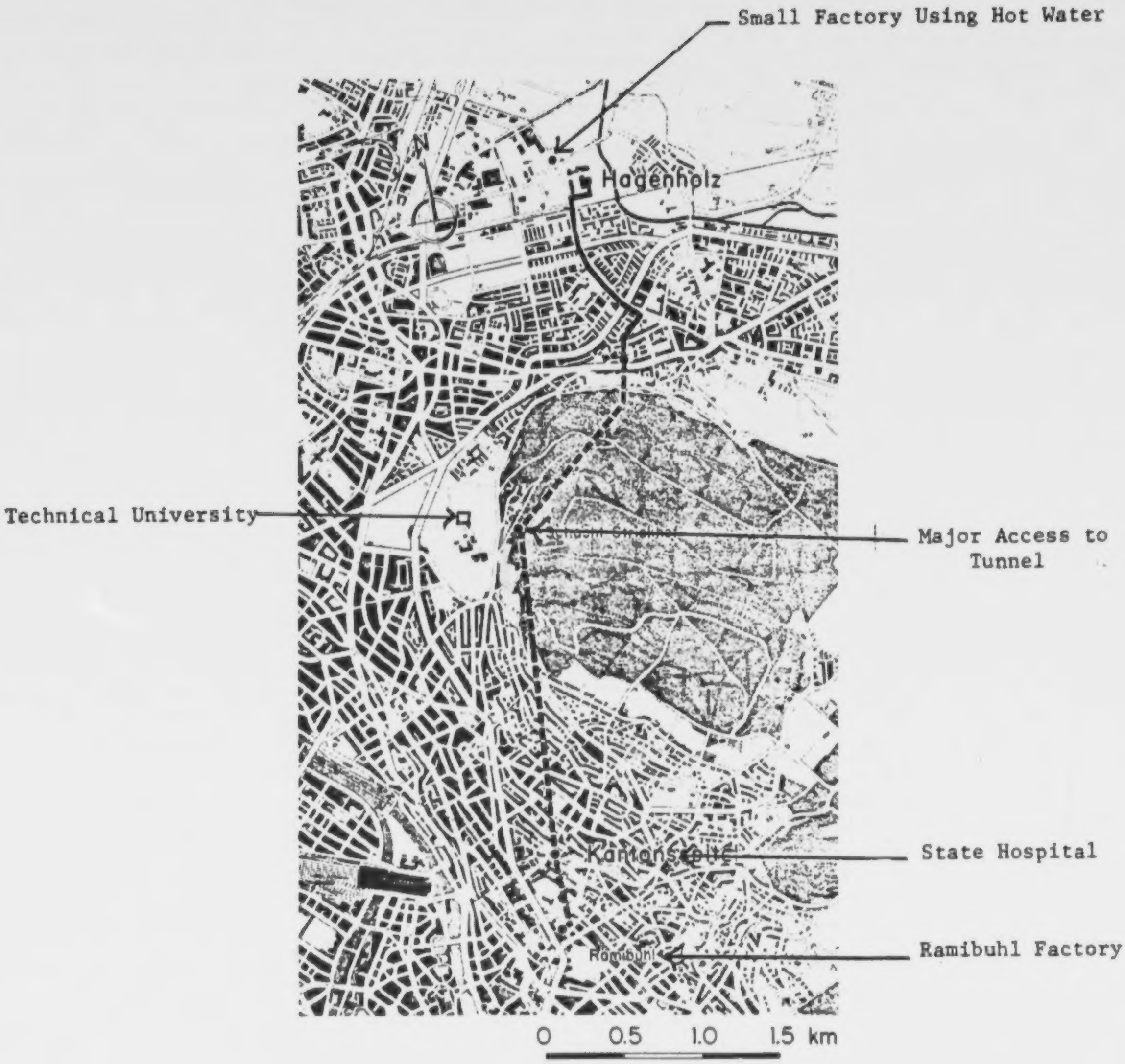

Small Factory Using Hot Water
Hagenholz
Technical University
Major Access to Tunnel
State Hospital
Kantonsspital
Ramibuhl Factory
Ramibuhl
0
0.5
1.0
1.5 km

FIGURE K-42. KANTON DISTRICT HEATING SYSTEM (5.3 km long)
USING 260 C (500 F) STEAM AT ZURICH, SWITZERLAND

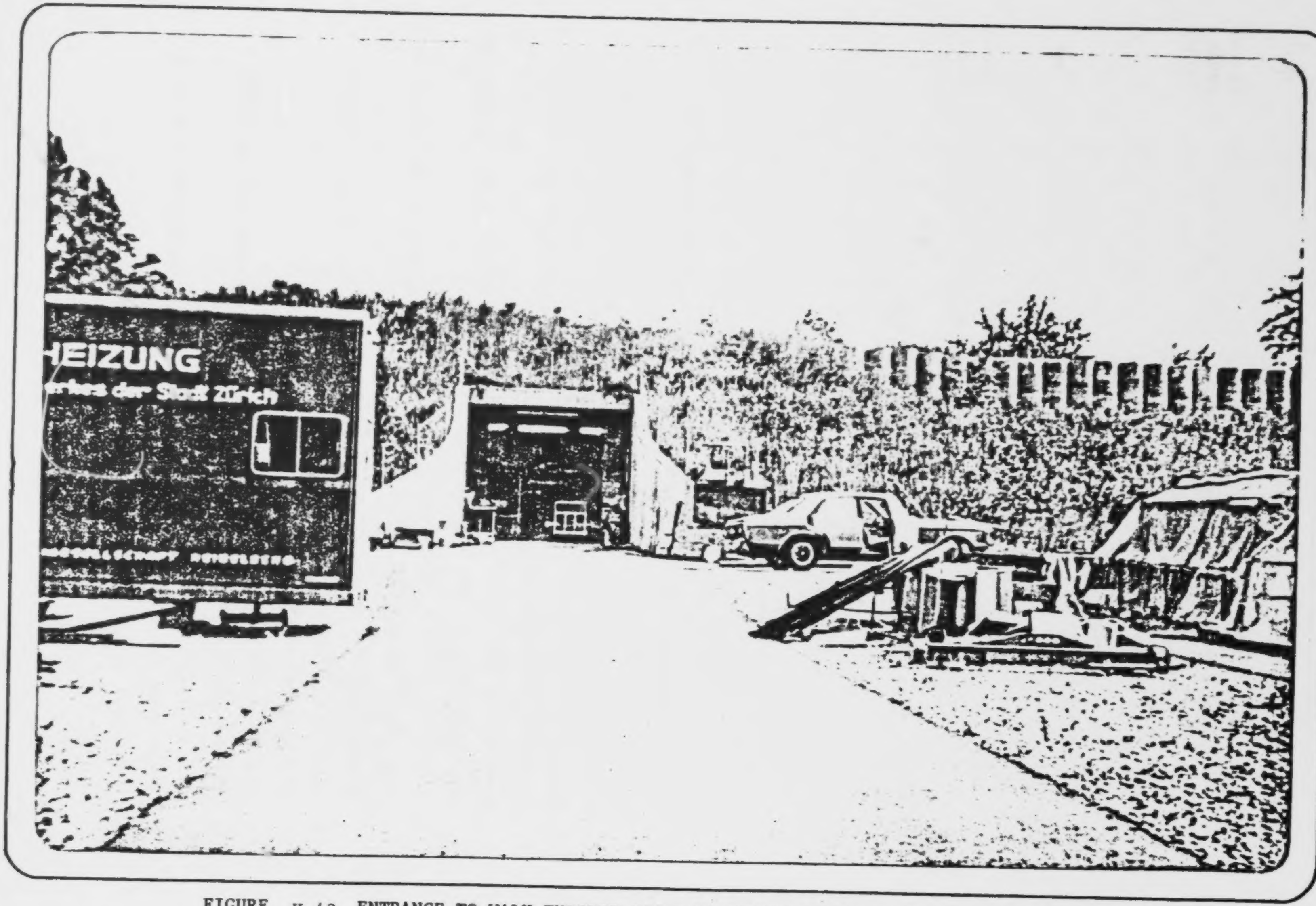
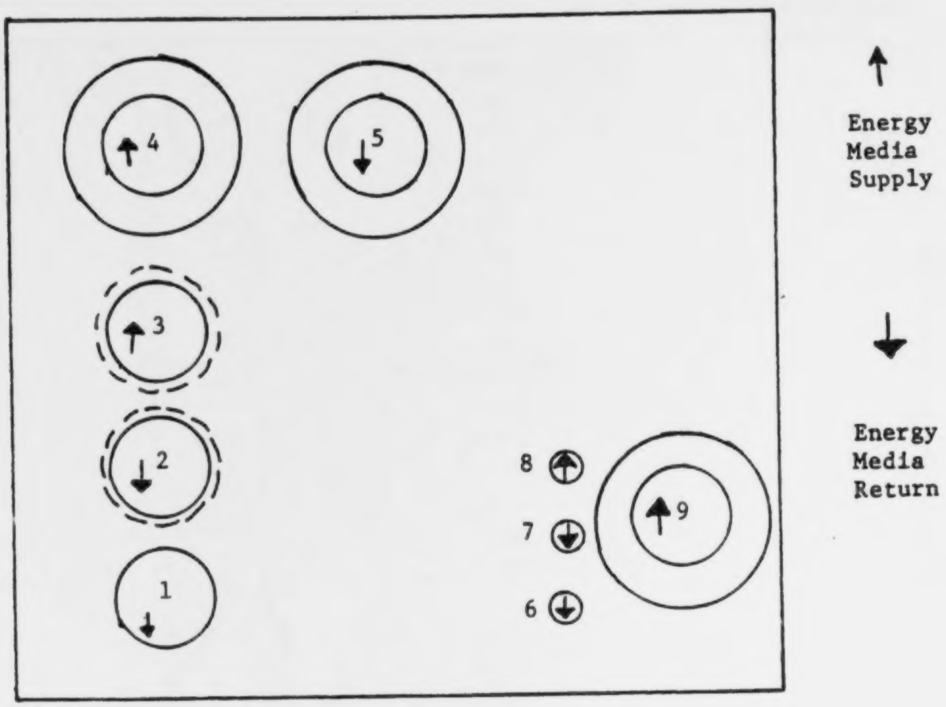

HEIZUNG
erkes der Stadt Zürich

FIGURE K-43. ENTRANCE TO WALK-THROUGH DISTRICT HEATING TUNNEL AT ZURICH: HAGENHOLZ



1. Steam condensate return from Kanton district heating network to Hagenholz 70-80 C.
2. Warm water return from Kanton district heating network to new oil energy plant.
3. Hot water supply from oil energy plant to Kanton district heating network for apartments 180 C.
4. Hot water supply from Hagenholz to EWZ plant to EWZ district heating network 130 C.
5. Warm water return from EWZ district heating network to EWZ plant to Hagenholz 100 C.
6. Condensate return from steam purge conditioning tank to Hagenholz (5 atmospheres).
7. Cooling water from City to pump for EWZ plant
8. Total purge condensate return from Kanton district heating network to conditioning tank 200 C (12-14 atmospheres).
9. Steam from Hagenholz to Kanton district heating network 5 km away 260-280 C (12-14 atmospheres).

FIGURE K-44. CROSS-SECTION SCHEMATIC OF PIPES IN THE DISTRICT HEATING SUPPLY AND RETURN TUNNEL AT ZURICH: HAGENHOLZ

Wärmeabgabe SBB und KZW 1976

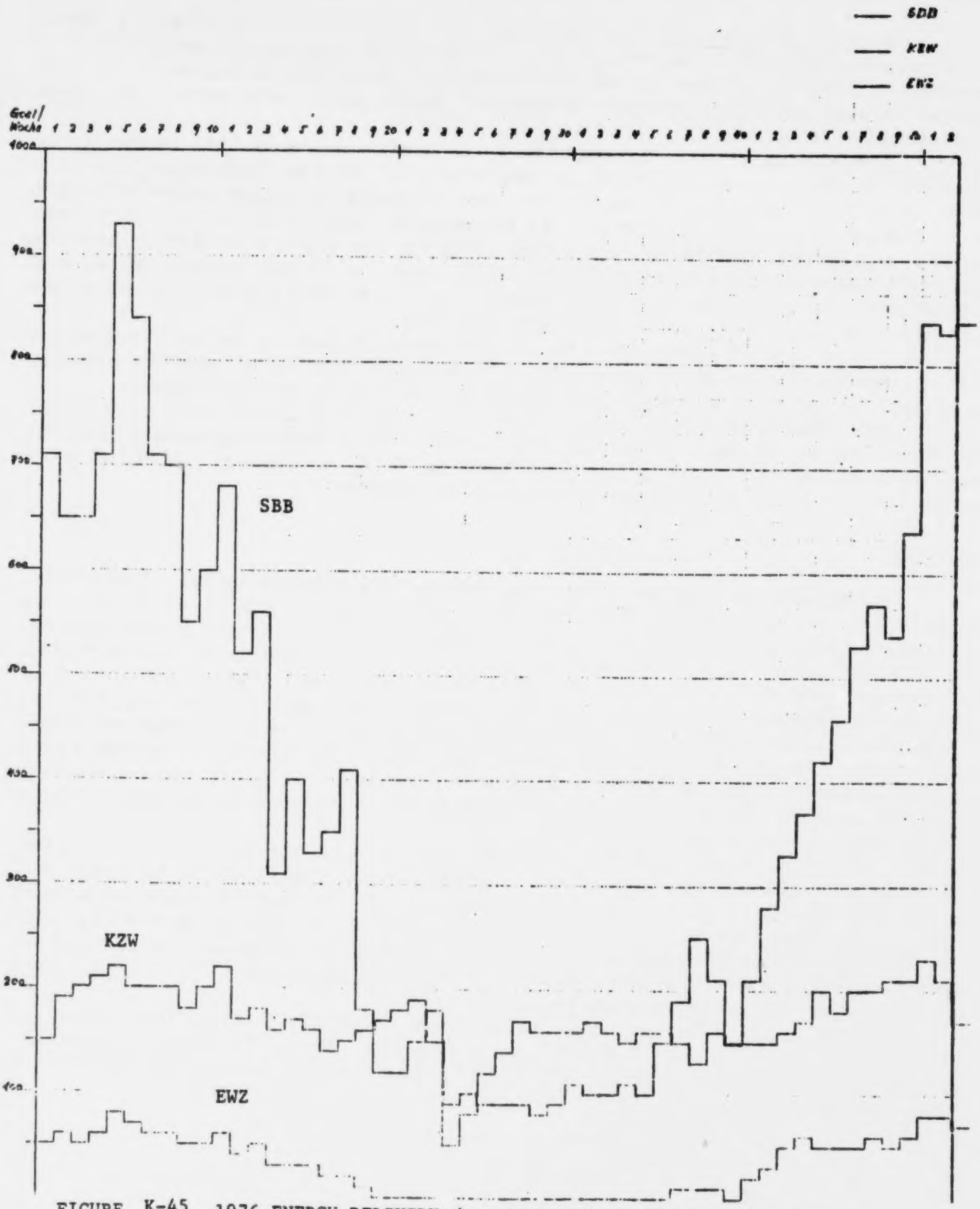


FIGURE K-45. 1976 ENERGY DELIVERY (WARMEABGABE) TO THE RAILROAD STATION, THE KZW AND EWZ

There is five to seven percent loss in "refuse-derived condensate" return to the plant by the district heating networks. However, more water by weight is returned to the RFSG plant.

Energy Marketing. Obtaining new publicly or privately owned large-volume customers is an art or skill practied by several of Abfuhrwesen's management people. There is no formal plan. However, management is very careful to seek potential customer contacts. Sales calls are made. No fixed rate schedule is used.

The energy plants are operated as profit centers that happen to be owned by the City. Each contract is negotiated. If the City must put in a large pipeline that will be deprecited over 40 years, a higher price will have to be charged for a unit of energy. As an example, Hagenholz sells its steam, at its own plant boundaary, at a low rate to the Kanton district heating network. However, Josefstrasse (1904, 1928, and 1979) has always owned and maintained its pipeline network; hence, its rates are higher. To lower the customer's price, quantity discounts are possible.

There are attempts by the Kanton district heating system (Heizamt, a sister organization to Abfuhrwesen) to sell to large apartment complex owners. No attempt is made to encourage individual homeowners to purchase steam.

Officials gave Battelle eight (8) page contract and financial worksheet as an example of a negotiated offer. This most interesting document between Abfuhrwesen and Migros (the leading food warehouse) is written in German and can be made available to interested parties.

The Hague

The energy available from this plant is electrical only. Internally, a small amount of steam at 4.3 bar (62 psi) (43,586 kg/m^2) (428 kPa) is extracted from the turbines for use in plant water heating and space heating. The electricity is generated in two 11.5 Mw 10,000 volt condensing turbogenerators operating at 40 bar (580 psia) (4000 kPa). About 15 percent of the power generated in 1975 was used internally. The remainder was supplied to the municipal network which is supplied principally by the large oil-fired power plant just across the Afvoer Canal from the waste plant. Because there is always ample cooling water available in the adjacent canal, the condensers are water cooled. There are, however, some plans to eventually use the turbine exhaust heat in the adjacent community.

During weekdays the contract with the municipal electrical organization requires the waste plant to generate for distribution at least 5.5 Mw between the hours of 6:00 a.m. to 11:00 p.m. If production falls below that level, the refuse to energy plant loses a bonus of DG 30,000 per month ($12,300 @ 2.44/$). Accordingly, considerable attention is given to preventive maintenance throughout the plant to enable reliable operation. The plant, as a whole, achieves 74 to 76 percent availability.

The refuse plant receives DG 0.03/Kwh ($0.012/kwh @ 2.44/$) from the city utility department of which it is a part. Thus, if both turbines are operating to produce a total of 23 Mw, the income would be DG 690/hr ($282.79/hr @ 2.44/$).

Dieppe (and Deauville)

The reader is referred to the Co-Disposal of Refuse and Sewage Sludge section for details of energy utilization. No energy is exported from either the Dieppe and Deauville plants.

Gothenburg: Savenas

Gothenburg has the largest hot water district heating system in Europe, most of it supplied by oil-fired boilers. The longest pipeline is 20 km (12.3 mi) one way. The steam produced from refuse at the Savenas plant is used to heat water to 120 C (248 F) at 16 kg/m^2 (228 psia) (1,570 kPa). The temperature drop in the district system is 50 C (90 F) and the hot water flow rate is about 420 m^3/hr (1,850 gpm).

Table K-15 shows the monthly results for 1976 on production and utilization of the energy from refuse as published in the GRAAB Annual Report. Figure K-46 from the same report shows the monthly trends in heat recovery and utilization. As one would expect, much heat produced in Summer months is wasted.

The sole energy output is hot water which is supplied to the large district heating system which serves about 200,000 flats and a nearby new hospital. The bulk of the 660 Gcal/h (2,620 Gcal/h) (2,763 GJ/h) produced for the system comes form the exhaust of back-pressure turbo-generators powered by oil-fired boilers.

In winter months, as seen earlier in Table K-15, the Savenas plant sends about 23,000 Gcal/mo to the system, an average of about 32 Gcal/h (127 G Btu/h) (134 GJ/h).

The Savenas plant wholesales the energy to the district heating system at about 40 S.Kr./Gcal ($2.02/106 Btu) (9.55 S.Kr./GJ) (0.0344 S.Kr./kw-hr thermal). The retail price* of this energy delivered to the customers is about 60 S.Kr./Gcal ($3.03/10^6 Btu).

Ten years ago in 1967, the system purchased 1 percent sulfur, No. 5 oil for 57 S.Kr./m3, about 63.3 S.Kr./tonne ($.04 gal). In 1976, it had increased to 450 S.Kr./m3 or 500 S.Kr./tonne ($.34 gal).

The total heating system serves 200,000 flats each of which averages 100 m^2 (1,076 ft^2) in living areas. The monthly bill is calculated from the following:

$$\text{Cost of heat} = 0.129 \times W \times B + \frac{18,000\ E \times k}{200}$$

in which

W = energy, Gcal
B = oil cost, S.Kr./m^3
E = capacity of the individual heat exchanger, Gcal/hr
K = cost of living index which was 400 in late 1977.

For a 100 m^2 flat, the value of E is about 0.085, which is based on a heat load of 0.085 Mcal/h-m^2 (31.3 Btu/h-ft^2). Thus, the maximum monthly cost to heat a flat if the heat operated at full capacity all month would be 3,414 S.Kr. ($682 @ S.Kr./$). Even operated at half capacity this would be $341/mo.

In arranging to serve a new hospital between 1 and 2 km (0.6 to 1.2 mi) away, the Savenas plant paid one third of the cost of 3.5 x 10^6 S.Kr. ($700,000) for the pipeline that had to go through hilly terrain.

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*This report uses 1975 to 1977 expense and revenue figures @ 5 S.Kr./$.

TABLE K-15. ENERGY PRODUCED BY SÄVENÄS PLANT IN 1976(2) (Courtesy GRAAB)

	Refuse Quantity Tonnes	Heat Recovered(1) Gcal	Heat Utilized Gcal	Proportion of Heat Utilized Percentage
January	20,500	28,300	23,300	97
February	18,900	27,700	23,900	99
March	21,900	33,400	27,600	97
April	21,600	31,800	22,100	82
May	21,400	31,900	14,700	54
June	21,000	26,400	9,900	44
July	17,000	26,400	7,900	35
August	19,800	25,900	13,700	62
September	22,500	31,900	19,000	70
October	21,600	29,100	19,600	79
November	22,200	28,900	22,600	92
December	21,100	33,400	28,500	98
Total	249,500	355,100	232,800	77
Electrical Equivalent		(413,000 MWh)	(271,000 MWh)	

(1) Includes about 15 percent as internally used heat. (1 Gcal = 1.163 MWh)

(2) Utilities consumed:

- Industrial Water - 0.64 m^3/tonne waste
- City Water - 0.26 m^3/tonne waste
- Electricity - 13,300 MWh; 53 KWh/tonne waste
- Residue Disposed - 73,000 tonne
- Residue Disposed - 29.3 percent of weight of waste

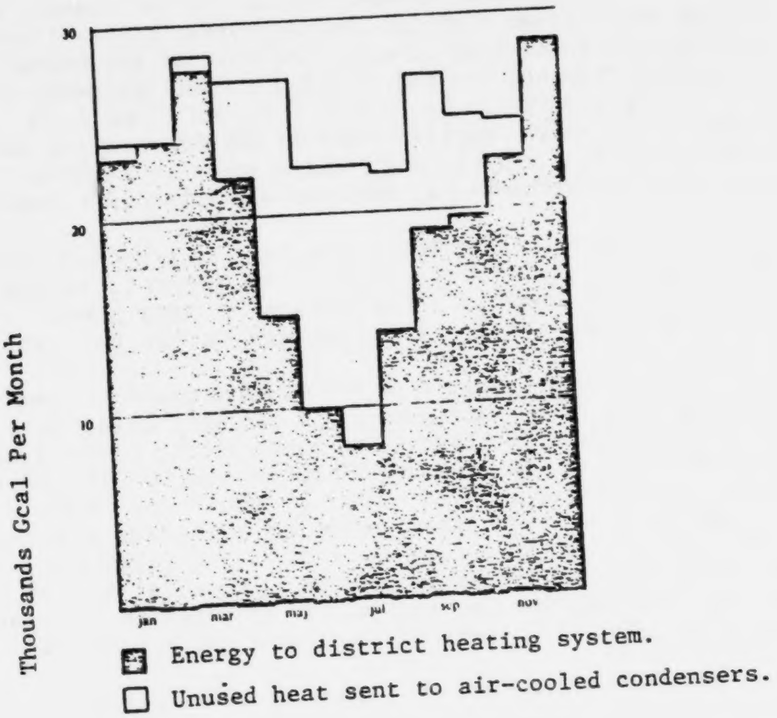


FIGURE K-46. MONTHLY TREND FOR 1976 OF HEAT PRODUCTION AND UTILIZATION IN GOTHENBURG (COURTESY GRAAB)

Uppsala

Figure K-47 illustrates schematically how the energy from refuse is integrated into the much larger district heating system operated by the Uppsala Kraftvarme AB (Uppsala Power Heat Corp.). The bulk of the energy required for the system is obtained from the burning of oil in a 200 mw power plant and in the central heating plants. At the bottom of figure is depicted the refuse-fired steam plant which supplies some steam for heating water for the central heating system plus process and heating steam to a number of industrial plants including the Fortia-Pharmacia, Abbatoir slaughterhouse, bakeries, and a laundry.

Table K-16 shows the operating data for the power and heating complex at Uppsala for the month of October, 1977. The steam-to-refuse production ration of 2.26 is slightly lower than the average for this plant.

Figure K-48 shows the installation additional hot water piping at Uppsala.

About half of the energy from refuse in Uppsala is used as hot water in district heating. The other half goes as 15 bar (217 psia) saturated steam to 10 industrial customers. The largest of these is the Fortia-Pharmacia Plant which has 1,250 employees and uses about 30 tonnes (66,000 lb) of steam/hour. The district hot water system receives water at 120 C (248 F) and returns it at 70 C (158 F). Some of the return water serves as condensor cooling water for the turbo-electric generators in the adjacent oil-fired power plant.

About 75 percent of the residences in the dense part of Uppsala are connected to the district heating system. It is hoped to increase this to 95 percent by 1980. In 1975, the length of distribution system was 160 km (100 mi).

There is a long-range plan for district heating supply in the Greater Stockholm area as shown in Figure K-24. The oil (primarily) and refuse cogeneration systems at Uppsala would be connected. The majority of the energy supply would be the waste heat of the Forsmark nuclear plant about 40 miles north of Uppsala and 90 miles from the southern Stockholm suburb of Haninge. The nuclear waste heat would be the baseload. Refuse burning at Uppsala would also be part of the base load because of the necessity to destroy waste regardless of the comparative costs. This plan is yet another fine example of coordinated forward thinking so common in Europe.

Horsens

Horsens is heated in part by a privately-operated hot water distribution system supplied from three oil-fired plants. In 1976, the operator of one of the systems requested supplemental hot water from the refuse plant which required the addition of a boiler and a 1.8 km (1.1 mi) transmission and return pipe which the city installed at a cost of about 2,500,000 D.Kr. ($432,000). With interest rates of 13 to 14 percent, it is estimated that the line will be paid for in 10 years. It will save about 2,500 tonnes (2,778 m^3) (17,475 barrels) of oil per year. At a cost of 600 D.Kr./tonne of oil ($0.34 gal), this represents a saving of 1,497,260 D.Kr. ($259,131/yr).

The new hot-water pipeline utilizes a new pipe insulation development by the organization of Danish communities which use district heating, Tjaerkam

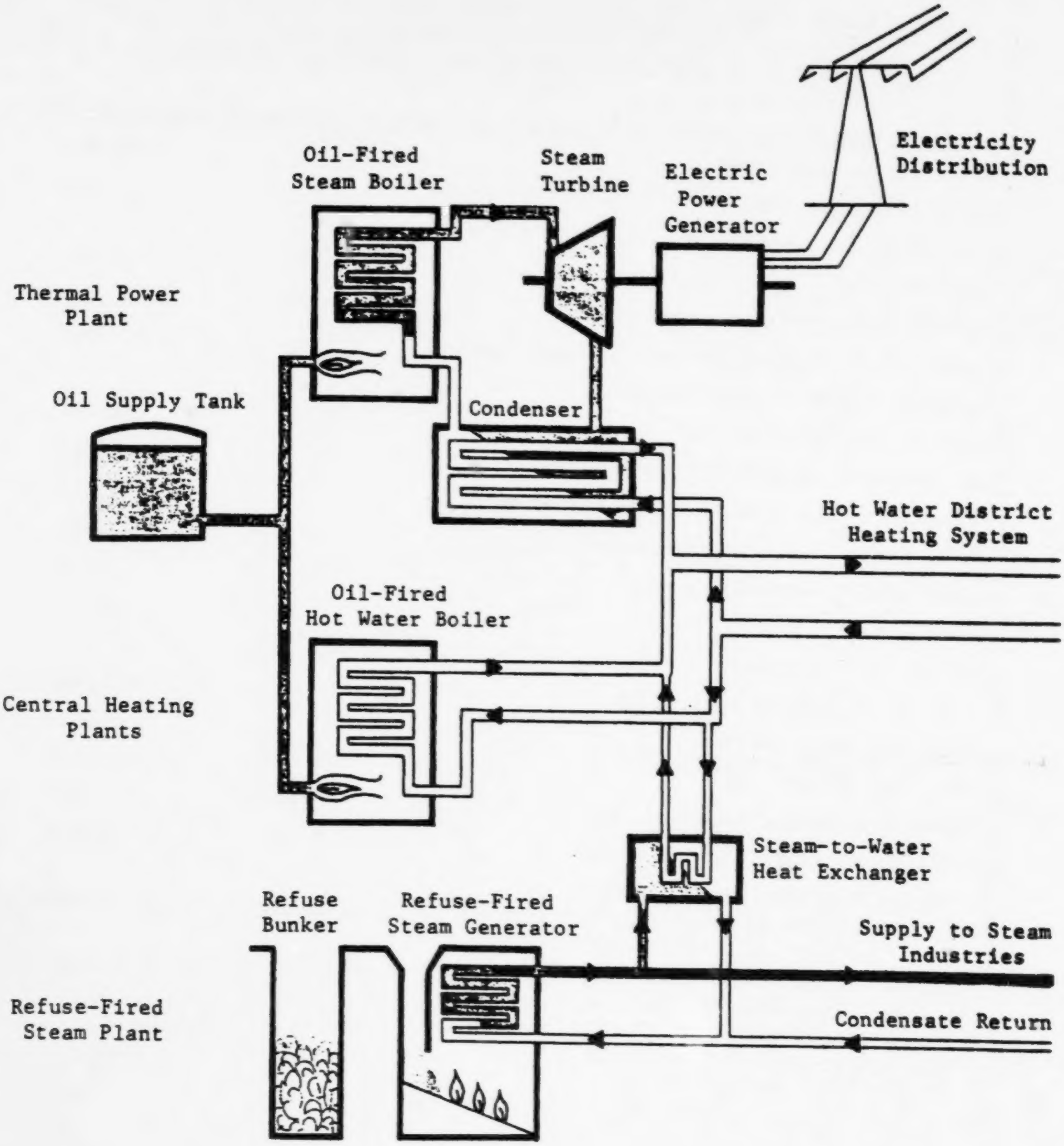

Electricity
Distribution
Oil-Fired
Steam Boiler
Steam
Turbine
Electric
Power
Generator
Thermal Power
Plant
Oil Supply Tank
Condenser
Hot Water District
Heating System
Oil-Fired
Hot Water Boiler
Central Heating
Plants
Steam-to-Water
Heat Exchanger
Refuse
Bunker
Refuse-Fired
Steam Generator
Supply to Steam
Industries
Refuse-Fired
Steam Plant
Condensate Return

FIGURE K-47. SCHEMATIC OF UPPSALA HEATING SYSTEM
(COURTESY UPPSALA KRAFTVARME AB)

TABLE K-16. TYPICAL AUTUMN MONTH OPERATION DATA FOR UPPSALA HEAT POWER COMPANY, OCTOBER, 1977 (INCLUDES DATA ON ALL 5 TYPES OF COMBUSTION*)

Total Oil Consumed, m^3	10,994.2
Refuse Burned, tonne	5,342
Steam Produced, tonne	
Refuse Plant	12,056.0
Other Steam Boilers (from oil)	3,333.7
Electricity Consumed by Refuse Plant, kwh	368,960
Steam-to-Refuse Production Ratio	2.26
Electricity Produced, Mwh	29,494.8
Oil Consumed in Electricity Generation, m^3	3,353
Electricity Consumed in Power Plant, kwh	151,316
Total Steam Delivered, tonne	12,231
Steam Used Internally, tonne	3,158.7
Condensate Returned, tonne	3,463.2
Electricity Consumed in Pumping District Heating Water, kwh	875,900
Waste Oil Received, kg	37,620
Waste Oil Burned, kg	0
Biological Wastes Received, kg	2,604
Oil Consumed for Boiler wastes, m^3	2,800
Dextrose Waste Received, kg	0

*1. Oil-Fired Power Plant (high temperature steam, electricity, hot water)
2. Oil-Fired District Heating Plant (hot water)
3. Refuse-Fired Energy Plant (low temperature steam, hot water)
4. Pathological Incinerator
5. Dextrose Incinerator

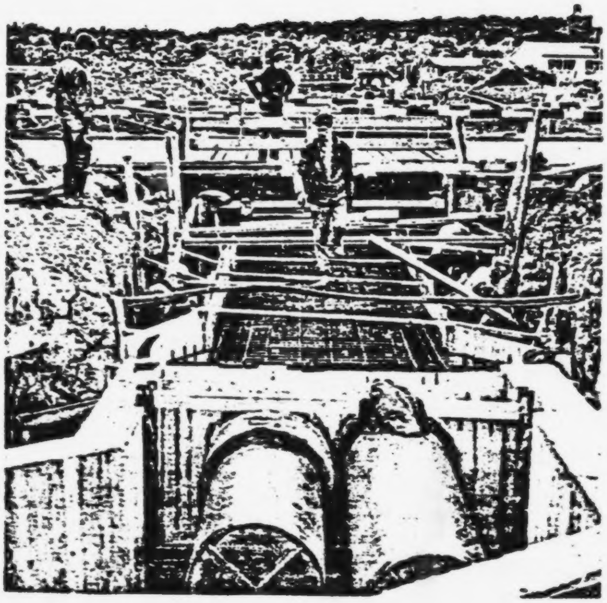


FIGURE K-48. INSTALLATION OF HOT WATER DISTRIBUTION PIPING (COURTESY UPPSALA KRAFTVARMEWERKE AB)

Pagniet of Nyborg. The trade name is TK-ISOBIT and is portrayed in Figure K-12. The conventional asphalt covering around the steel pipe is filled with porous insulating mineral granules. The protective covering can be repaired by enclosing any gapor break in the covering in a temporary shield, then filling the gap with the granules followed by hot asphalt. The assembly is believed to be very effective in insulating the pipe while preventing corrosion.

Since the hot water boiler and 1.8 km connecting pipe has been in operation only since May, 1977, there has not been enough time to accumulate much data on the new energy now being fed to one of the private district heating systems. However, some planning is being done regarding a possible 2.5 km (1.5 mi) connecting line to another plant six times as large as the first one. The cost of the line through part of the city would be 6 million D.Kr. ($1 million). If that plan materializes, the plant would install its second boiler-furnace and much more refuse would be needed from neighboring communities.

The district heating plant is charged for the energy recieved at a rate calculated as 0.12 times the cost of heavy oil per tonne. When the refuse plant begun supplying hot water to the system in May, 1977, oil cost 540 D.Kr./tonne (30.7 cents/gal @ 6 D.Kr./$). By September, 1977, the cost was 555 K.Kr./tonne and a government tax of 80 D.Kr./tonne brought the total to 635 D.Kr./tonne (36.1 cents/gal). Therefore, in May, the charge for the heat delivered as heated water was 64 D.Kr./Gcal and rose to 76.2 D.Kr./Gcal ($3.02/M Btu @ D.Kr./$) in September, 1977 at the time of this visit. For comparison, a homeowner in Horsens buying distillate oil for his residence in September, 1977, paid 1,000 D.Kr./tonne (85.3 D.Kr./Gcal) (50.5 cents/gal) ($3.58/MBtu), including taxes (based on #2 oil with a specific gravity of 0.8 and a higher heat value of 141,000 Btu/gal).

Copenhagen: Amager

Figure K-49 shows the rufuse burning plant in the foreground with the larger conventional power plant, owned by Copenhagen Gas and Electric, in the background. The refuse plant is a base load plant. The conventinal plant, being the peaking plant, can adjust its operations to ensure steady energy delivery.

The refuse plants hot water is sent to the electricity plant, but it is not used to make electricity. Rather, the hot water is combined with the electricity plant's waste heat and together they supply the Amager Island district heating network.

The Amager refuse plant sells its hot water for a lower price per 1000 pounds then does the West plant for several reasons: (1) the water temperature is lower at Amager; (2) the single distribution pipe to the power plant is only a couple of hundred feet; (3) Copenhagen Gas and Electric Authority (CGEA) handles the district heating distribution, so the refuse plant has no distribution expenses, and (4) the refuse plant's energy competes with the CGEA plant's waste heat.

Roughly 1.2 Gigacalories can be added to water per tonne of refuse burned. At Amager, the annual average sale price to CGEA varies from 55 to 60 D.Kr. per Gcal. The formula is somehwat unique. If the CGEA electric power plant is working and producing its own waste heat, then the energy value paid to the refuse plant is 60 percent of the comparable oil price for the same

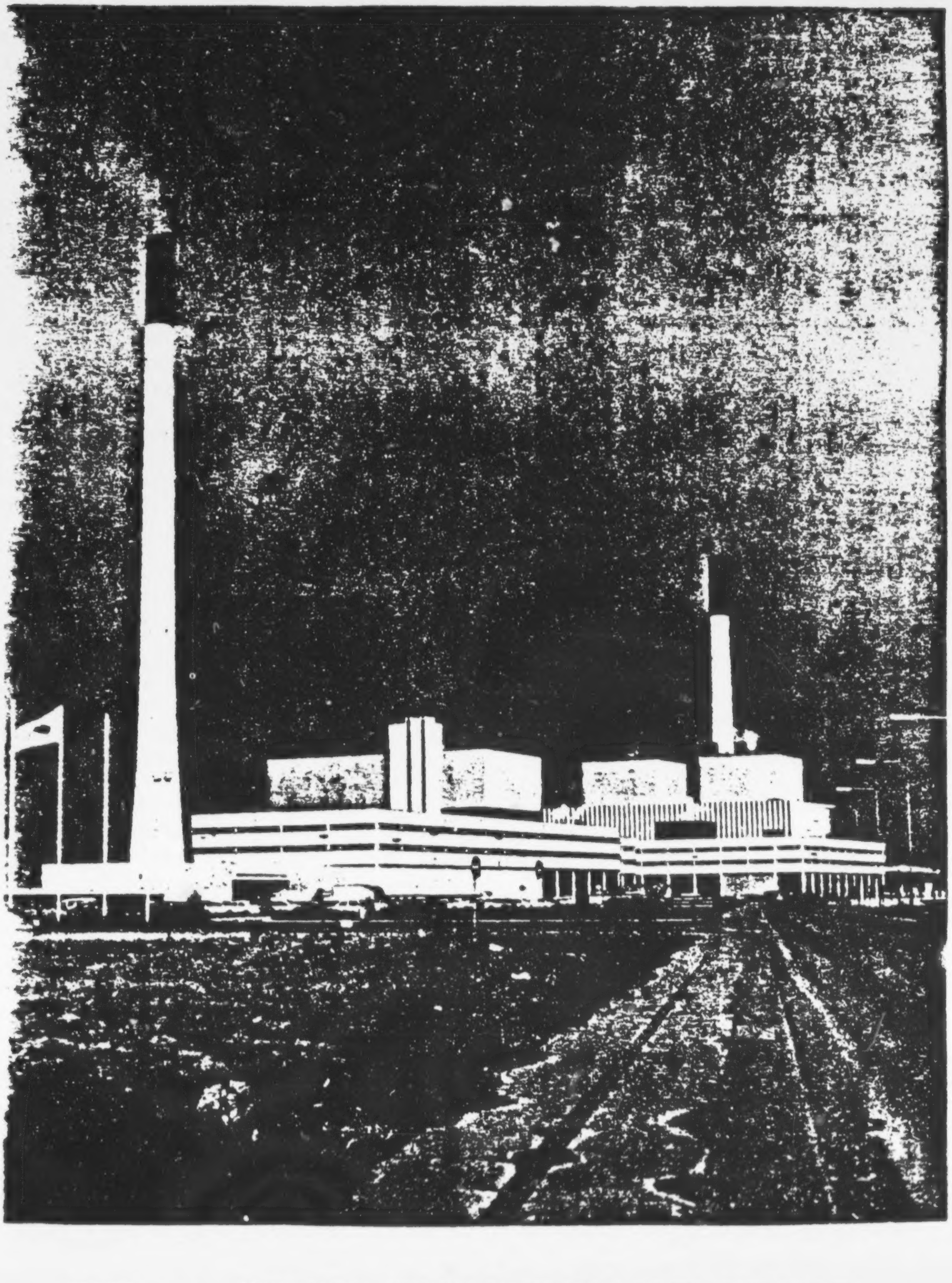


FIGURE K-49. COPENHAGEN: AMAGER'S REFUSE FIRED ENERGY PLANT IN THE FOREGROUND AND THE OIL FIRED PLANT IN THE BACKGROUND energy. However, if the electric power plant is not in operation, then the refuse plant receives 100 percent of the comparable oil price. All calculations are based on heating value and not on volumes of water.

Under this arrangement, the refuse plant sold 70 percent of its production during 1975-1976. The percentage has been increasing from year to year. There are future plans to run a pipe under the canals connecting Amager Island to the Copenhagen downtown district heating network.

Heavy insulated water pipes are shown in Figure K-50. The pumps used to send steam to the combined district heating system are shown in Figure K-51. Amagker produces hot water at 115 to 120 C (239 to 248 F) at 6 kg/cm^2 (88 psi). As stated before, this is lower quality hot water than the superheater water at West. Amager sends its share of the energy to the power plant which then distributes it to the district heating system shown in Figure K-52. Of the total energy sold, 50 percent goes directly to household radiators. The other 50 percent transfers its energy through water-to-water heat exchangers.

The total energy delivered to the district heating system is shown in Figure K-53. Note that the summer base load is usually 8,000 Gigacalories while the winter peak load is around 20,000 Gigacalories. Presumably a few industries, hospitals, etc. provide the base load in the summer.

The 1975-1976 energy sold amounted to 188,253 Gigacalories for a revenue of 4,877,703 D.Kr. Dividing revenue by quantity results in an average sale price of 25.91.

> Several years ago Mr. E. Blach was Volund's Chief Engineer. Excerpts from one of his technical papers in included below.
>
> "It will always be economically profitable to exploit the heat from an incinerator plant, whenever possible.
>
> "The heat can be used for district heating, various industrial purposes, drying and burning of sewer sludge or other sludge production of electricity.
>
> "If the heat cannot be exploited other arrangements must be made to cool the 900-1000 C, hot flue gas to about maximum 350 C, before it is led into the precipitator and the chimney.
>
> "Such a cooling of the flue gas can be done by adding air, water spray, a combination of water spray and air, and eventually be letting the flue gas through a waste heat boiler and then cool the water or steam.
>
> "Initial expenditures of plant as well as operational costs for the cooling plant with air, water spray, or a combination are just as the costs of an actual plant for heat exploitation with a possible supplementary air cooler. The sale of heat, therefore, is an actual working income, which contributes essentially to the operation of the plant, even with regard to the extra costs for repair caused by wear and corrosion in the convection part of the boiler.
>
> "Least profitable is the production of electricity as the costs of high pressure boilers and turbines are too high and the efficiency too low compared with the low price at which the big power stations can produce the electricity. There is a great need for drying and burning sludge, and the use of waste heat for heat for district heating or industrial purposes has, therefore, up to now been the solution which technically and economically has shown the best results."

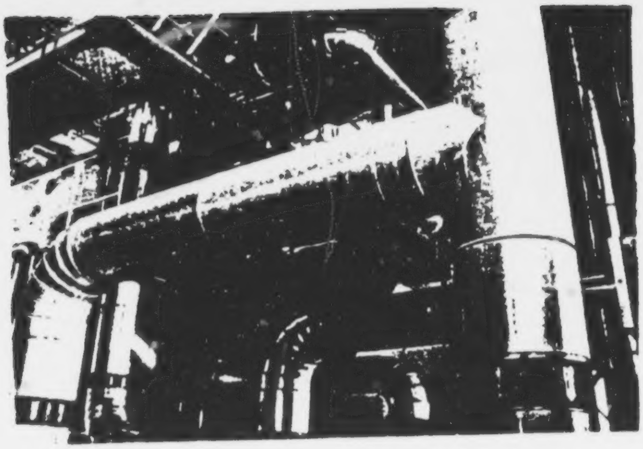


FIGURE K-50. INSULATED HOT WATER PIPES LEAVING BOILER AT AMAGER

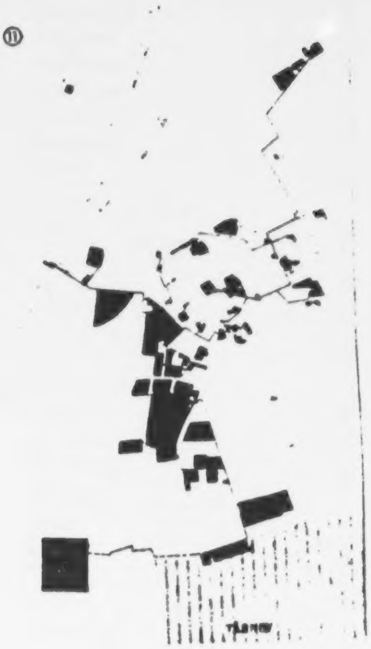


FIGURE K-52. MAP OF DISTRICT HEATING NETWORK OF AMAGER ISLAND

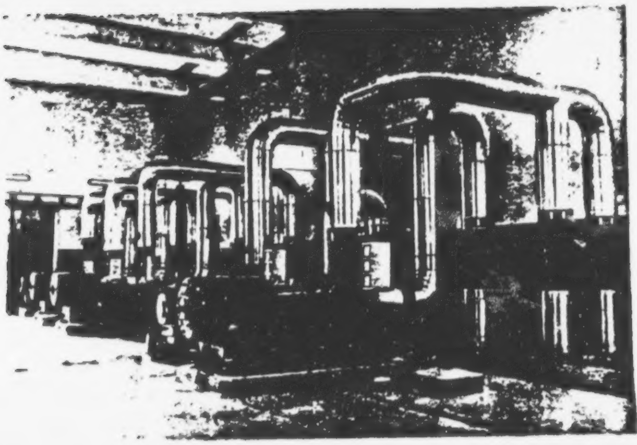


FIGURE K-51. PUMPS TO SEND HOT WATER TO THE POWER PLANT WHICH SENDS THE HOT WATER TO THE DISTRICT HEATING NETWORK AT AMAGER

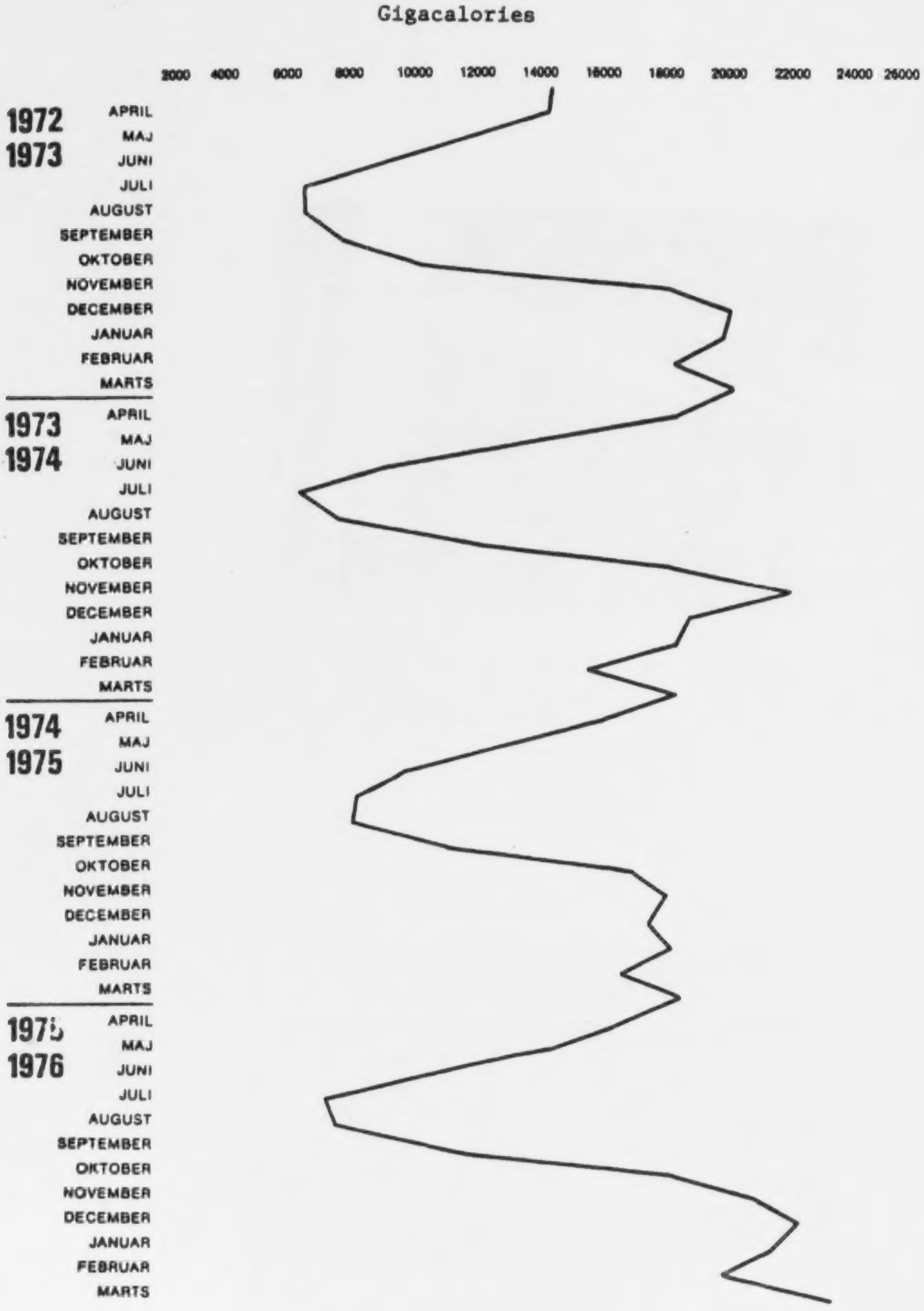


FIGURE K-53. ENERGY DELIVERY TO THE DISTRICT HEATING NETWORK

Copenhagen: West

West produces superheater water at 160-170 C (320 to 338 F) at 15 kg/cm^2 (235 psi). As stated before, this is at a higher quality than the hot water at Amager because the key customer, the Copenhagen County Hospital had already planned its utilities as follows:

- Hot water into radiators for space heating,
- Hot water into the heat transfer device to make steam for use in the sterilizatin autoclave.
- Hot water into the absorption chiller to make cold water for air conditioning in the summer.

As is true of most waste-to-energy development, the large original charter energy user has much influence over plant design. The hospital location, along with the other current (1977) customers is shown in Figures K-54 and K-55a. The network is basically a long main pipe, 6,000 m (3.5 miles) with several small branches. A school on the system is shown in Figure K-55b.

There are no single family homes on the system at present. However, officials are open to supplying hot water to associations of homeowners at a later data.

Assuming that a single family homeowners association were to desire service,the association would have to obtain 50 percent participatin before it would be worthwhile putting in additional piping capacity. A second condition would be the likelihood of eventually raising to 70 percent of the single-family homes in a continguous area.

There is more of a tradition favoring district heating of single-family homes in the western Jutland peninsula than around Copenhagen. Actually, the company has not tried to get homeowners associations because the main pipe cannot carry any more heat.

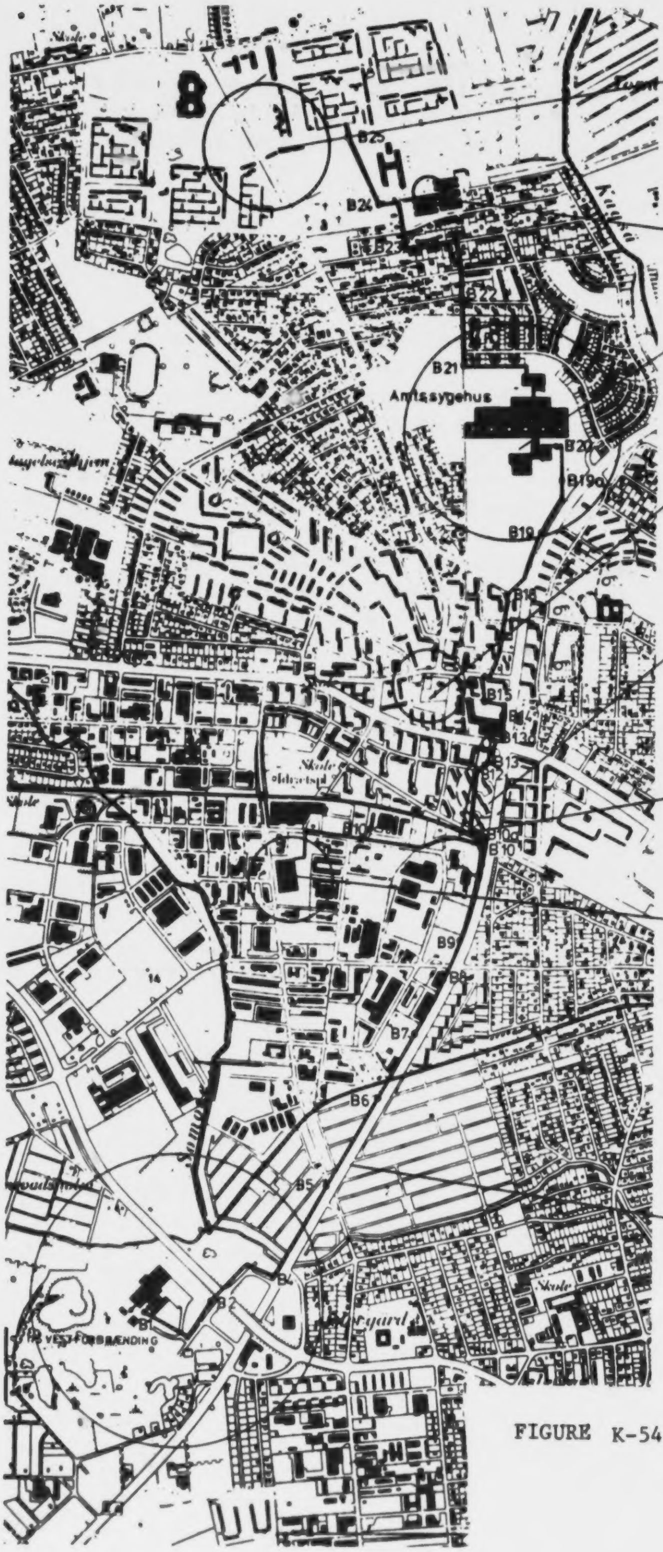
Now with four furnaces, 80 percent of the heat produced is used. This is equivalent to 40,000 tonnes (44,000 tons) of oil per year. They hope to more than double district heating demand by 1975. If so, most of the increase will have to come from oil-fired furnaces. One of the oil-fired boiler plants shown in Figure K-55d. It is next to the chimney at the West refuse-burning plant. Under the plan (where demand doubles), the refuse-derived energy utilization could rise to 90 percent--never really approaching close to 100 percent.

The superheater water at 160 to 170 C (320 to 338 F) is sent out in a main concrete culvert as shown in Figure K-56. The exit and return pipes are imbeded in gravel. Each pipe is surrounded by 100 mm (4 inches) of mineral wool. The culvert is then covered with a strong plastic lid. Varrying configurations are used in the branches. The used and cooler water 70 C (158 F) is returned in an adjoining pipe in the same culvert.

The main pipe is constructed with occasional manholes (shown as B1 through B25 in Figure K-54) that permit inspectors to run cylindrical television cameras up and down the water pipes to locate leaks.

EXISTING DISTRICT HEATING NETWORK

1976/77


B25
H
B24
B23
B22
B21
Amtssygehus
B20
B19a
B19
B15
B14
B13
B12
B10
B9
B8
B7
B6
B5
B4
B3
B1
VESTFORBRÆNDING

Lille Birkholm Heat Co. a.m.b.a.

about 2000 apartments, nursing homes, a school, etc.
19 Gcal/hr

Køllegaard-Dyrholm School

1,2 Gcal/hr

Copenhagen County Hospital

35 Gcal/h up to about 45 Gcal/hr in 1985. Summer heat consumption for cooling

Herlev District Heat Co.

Shopping Center, City Hall, Library, School, Apartments, etc.
6,5 Gcal/hr

Near the RR-station -- RR Ground

Apartments
2,3 Gcal/hr
Connected in mid-77 1977)

Private Bank

0,24 Gcal/hr

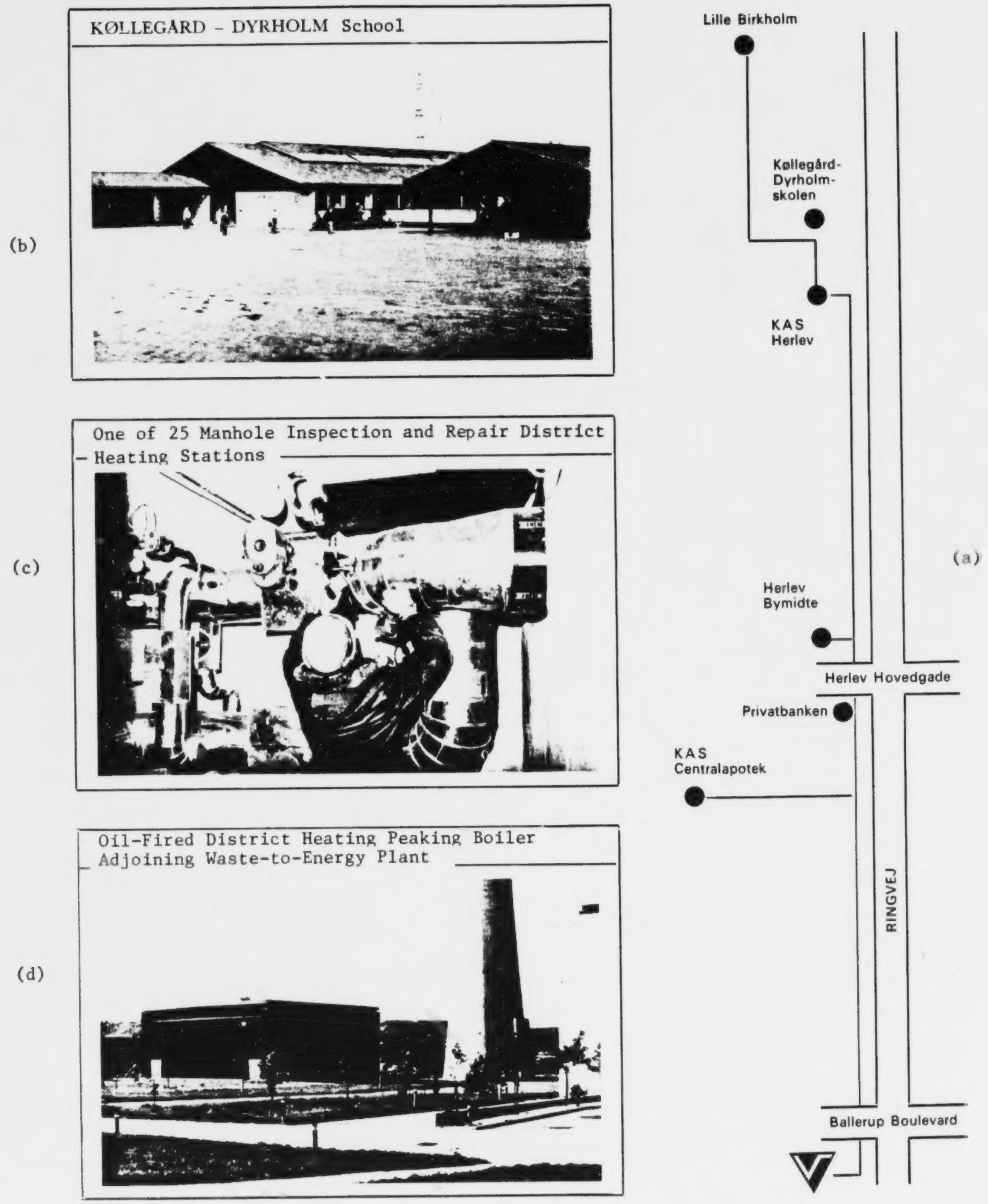
Copenhagen County Pharmacy at Herlev, under construction

6,5 Gcal/hr

TILSLUTNING I ALT About ca. 70 Gcal/hr or about 50% of the maximum capacity of the main lines

Hovedledninger fra VF til Københavns Amts sygehus

FIGURE K-54. MAP SHOWING DISTRICT HEATING CUSTOMERS



KØLLEGÅRD – DYRHOLM School

One of 25 Manhole Inspection and Repair District Heating Stations

Oil-Fired District Heating Peaking Boiler Adjoining Waste-to-Energy Plant

Lille Birkholm
Køllegård-Dyrholm-skolen
KAS Herlev
(b)
(c)
(a)
(d)
Herlev Bymidte
Herlev Hovedgade
Privatbanken
KAS Centralapotek
RINGVEJ
Ballerup Boulevard

FIGURE K-55. DISTRICT HEATING SYSTEM AT COPENHAGEN:WEST

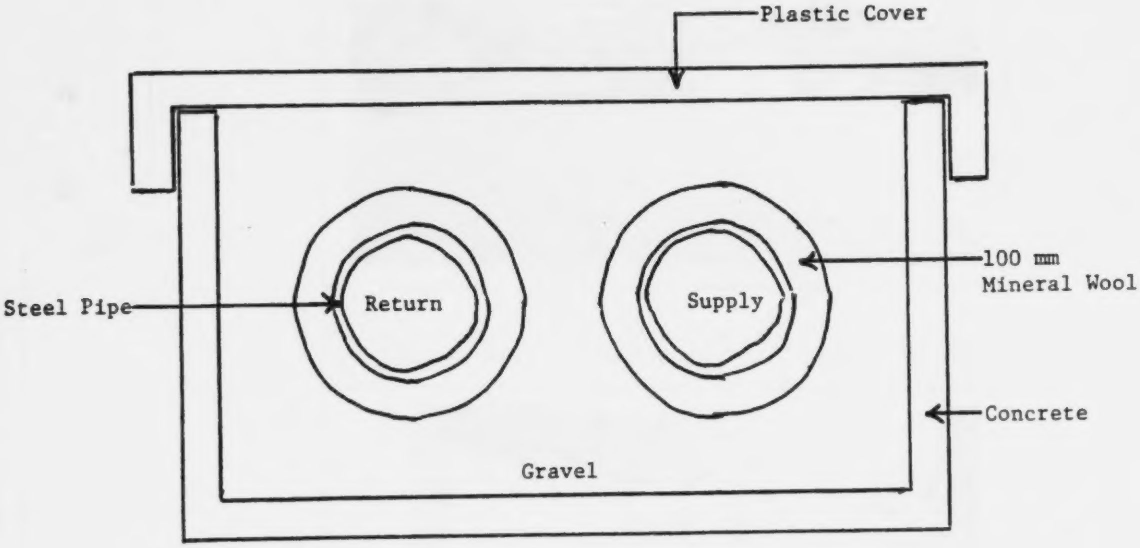

Plastic Cover
Steel Pipe
Return
Supply
100 mm
Mineral Wool
Concrete
Gravel

FIGURE K-56. DISTRICT HEATING PIPE TUNNEL AT COPENHAGEN: WEST

ECONOMICS

The economics section is divided into several parts as follows:

- General Comments About the Capital Investment Costs
- Trends in Initial Capital Investment Costs per Daily Ton
- Specific Comments About Capital Investment Costs of Visited Systems
- General Comments About Expenses
- Specific Comments About Expenses
- Finance General Comments
- Finance of Visited Systems

General Comments About the Captial Investment Costs

Capital investment costs are displayed in Table L-1 for the 15 plants visited. The numbers presented are those provided by local officials. The definition of the numbers are not necessarily consistent. The reader will have to review the specific comments to sort out the data depending on the type of numbers desired.

Land, for example, is sometimes included if overtly paid for. However, if the refuse fired energy plant was built on the grounds of an existing municipally owned Energy and Environmental Park, the land might be considered free.

Some operators have "within-the-grate" accomiting schemes that have combined and inseparable investment data. For example: consider the newly constructed RFSG, administration building, truck repair building and bicycle hall that were funded out of one financing instrument.

American vendors of European licenses were quick to discourage placing too much emphasis on the following investment figures. What they hopt to market in America in the 1980's bears little resemblance to what was built in the late 1960's or early 1970's as discribed in this report. To quote from the 1976 "Solid Waste Management Guidelines" as published by the U.S. EPA:

> "It is EPA's firm belief that attempts to predict (and compare) costs of various types of plants in a general way, apart from local circumstances, is more likely to mislead than inform. The range of assumptions regarding specific design, reliability, markets and other factors is too great to make such an analysis meaningful."

Initial Capital Investment Cost per Daily Ton

Initial capital investment cost per daily ton capacity has risen dramatically from 1960 the present. Earlier values of $13,000 per daily ton compare with 1975-76 values of $50,000 to $90,000 per ton. More recently there have been some American proposals near $100,000 per daily ton capacity. These numbers are displayed in Figure L-1. There are six general reasons for this dramatic price growth:

TABLE L-1. SUMMARY OF CAPITAL INVESTMENT

	Total Facility				
	Energy and Envir. Biggest Cost	Part Refuse to Energy Plant by Staff	Chute to Stack Costs Only Mech. & Elec.	Finance Year	Refuse Fired Steam Generator Total Capital Investment Best Estimate for Comparative Purposes
Werdenberg	18,000,000 S. Fr.	13,000,000 SF			13,000,000 SF
Baden-Brugg		16,400,000 SF		1970	16,400,000 SF
Duesseldorf Units #1-4		34,500,000 DM	15,500,000 DM	1965	46,300,000 DM
Units #5			11,800,000 DM	1972	
Wuppertal	126,000,000 DM	126,000,000 DM	54,400,000 DM	1975	126,000,000 DM
Krefeld		60,000,000 DM		1976	60,000,000 DM
Paris:Issy		110,000,000 F. Fr.		1962	110,000,000 F.Fr.
Hamburg:Stellinger-Moor		48,000,000 DM	25,000,000 DM		48,000,000 DM
Zurich:Hagenholz Units #1-2	56,000,000 S. Fr.	45,694,000 S. Fr.	23,000,000 S. Fr.	1969	59,694,000 S.Fr.
Units #3		14,000,000 S. Fr.	11,430,000 S. Fr.	1973	
The Hague #1-3		45,000,000 Gl.		1967-68	62,000,000 Gl.
#4		17,000,000 Gl.		1973-74	
Diepppe	13,663,000 F. Fr.	7,933,000 F. Fr.	6,400,000 F. Fr.	1969	8,683,000 F.Fr.
		750,000 F. Fr.		1971	
Gothenburg	120,000,000 S. K.	98,000,000 S. Kr.		1971	98,000,000 S.Kr.
Upsala Fur. 1, 2 Boiler 1		3,400,000 S. Kr.		1960	11,050,000 S.Kr.
Fur. 3, Boiler 2			1,000,000 S. Kr.	1965	
Fur. 4, Boiler 3			4,000,000 S. Kr.	1970	
Crane, ESP, Shear, etc.				1971	
To replace entire Uppsala systems in 1977 dollars	60,000,000 S. K.				
Horsens (with spray cooling tower)		11,094,423 D. Kr.	6,514,873 D. Kr.	1973-74	18,203,000 D.Kr.
Boiler & Pipe		7,108,544 D. Kr.		1976-77	
Copenhagen:Amager		117,600,000 D. Kr.	45,000,000 K. Kr.	1970-72	157,600,000 D.Kr.
Improvements		40,000,000 D. Kr.		1973-77	
Copenhagen:West Units #1-3		140,580,022 D. Kr.		1969-70	204,973,000 D.Kr.
Units #4 etc.		64,392,612 D. Kr.		1975-76	

TABLE L-1. SUMMARY OF CAPITAL INVESTMENT (Continued)

Weighted Average Year of Investment used to Select Exchange Rate	Exchange Rate U.S.$	U.S. Dollars in Weighted Ave. Year	Actual 1976 Tonnes Per Year	Tons Per Year	Tons per Day at 365 Days/Yr.	Capital Cost Per Daily Ton Capacity
1973	3.244	4,007,000	26,018	28,620	78	51,103
1970	4.316	3,800,000	41,693	45,862	126	30,243
1967	3.999	11,578,000	297,359	327,095	896	12,920
1975	2,622	48,055,000	178,000	195,800	536	89,582
1976	2.363	25,391,000	114,000	125,400	344	73,905
1962	4.900	22,449,000	588,904	647,794	1,775	12,649
1971	2.622	18,307,000	420,680	462,748	1,268	14,440
1970	4.316	13,831,000	223,595	245,955	674	20,525
1970	3.598	17,237,000	229,000	251,900	690	24,976
1969	5.558	1,562,000	14,892	16.381	45	34,804
1971	4.858	20.173,000	242,536	266,790	731	27,599
1967	5.165	2,139,000	52,040	57,244	157	13,639
1975	6.178	2,946,000	18,909	20,800	57	51,697
1971	6.290	25,056,000	255,000	280,500	768	32,604
1971	6.843	29,954,000	234,230	257,653	706	42,434
TOTAL AVERAGE-1971		246,485,000 16,432	2,936,856 195,790	3,230,542 215,369	8,851 590	35,541

FIGURE L-1. REASONS FOR 10-FOLD INCREASE IN CAPITAL INVESTMENT COSTS OVER 10 YEARS FOR EUROPEAN REFUSE FIRED ENERGY SYSTEMS

- **INFLATION**
  - **LAND**
  - **CAPITAL EQUIPMENT PURCHASES**
  - **CONSTRUCTION SERVICE FEES**
  - **CONSTRUCTION LABOR AND MATERIALS COST**
- **EXCHANGE RATE DEVALUATION**
- **CORROSION PROTECTIVE EQUIPMENT DESIGNS**
- **ARCHITECTURE AND LANDSCAPING FOR NEIGHBORHOOD ACCEPTANCE**
- **MORE COMPLEX ENERGY USE SYSTEMS**
- **MORE AIR POLLUTION CONTROL EQUIPMENT**

Inflation. Generally speaking, with the exception of West Germany, costs of construction have inflated more in Europe than in the United States.

Exchange Rate Devaluation. Table L-2 has been the most used table in the report preparation. Most of the conversions have been from local currencies into U.S. dollars for a particular year. The reader should remember this general rule:

Divide the Eurpean local currency number by the exchange rate with the U.S.

Corrosion Protective Equipment Designs. In other report sections the threat of metal wastage has been elaborately discussed. In fact, forty ways to reduce corrosion and erosion have been identified in this study, and most ways necessitate higher investment.

Architecture and Landscaping for Neighborhood Acceptance. As close-in European land has become more precious, the few remaining spaces near the city's cove are often in household neighborhoods or near major above ground level highways. The compromise with local citizens has occasionally been to promise a beautiful plant surrounded by exceptional landscaping. It's a situation of, "I don't want a dirty garbage plant in my neighborhood. But if you make it as attractive as in those drawings and that scale model, it might be all right."

The two almost identical Copenhagen plants, each withh a 864 ton per day capacity, had very different capital costs. Granted not all of the variance can be explained by the aesthetic budget for architecture and landscaping, but aesthetics were the major cause. Amager, localed on land recovered from the sea in an industrial area, has a $32,604 per daily ton figure while the more aesthetically pleasing West plant costs $42,434 per

TABLE L-2 EXCHANGE RATES FOR SIX EUROPEAN COUNTRIES, (NATIONAL MONETARY UNIT PER U.S. DOLLAR) 1948 TO FEBRUARY, 1978(a)

	Denmark Kroner (D.Kr.)	France Francs (F.Fr.)	W. Germany Deutsch Mark (D.M.)	Netherlands Guilders (Gl.)	Sweden Kronor (S.Kr.)	Switzerland Francs (S.Fr.)
1948	4.810	2.662	3.333	2.653	3.600	4.315
1949	6.920	3.490	4.200	3.800	5.180	4.300
1950	6.920	3.499	4.200	3.800	5.180	4.289
1951	6.920	3.500	4.200	3.800	5.180	4.369
1952	6.920	3.500	4.200	3.800	5.180	4.285
1953	6.920	3.500	4.200	3.786	5.180	4.288
1954	6.914	3.500	4.200	3.794	5.180	4.285
1955	6.914	3.500	4.215	3.829	5.180	4.285
1956	6.914	3.500	4.199	3.830	5.180	4.285
1957	6.914	4.199	4.202	3.791	5.173	4.285
1958	6.906	4.906	4.178	3.775	5.173	4.308
1959	6.908	4.909	4.170	3.770	5.181	4.323
1960	6.906	4.903	4.171	3.770	5.180	4.305
1961	6.886	4.900	3.996	3.600	5.185	4.316
1962	6.902	4.900	3.998	3.600	5.186	4.319
1963	6.911	4.902	3.975	3.600	5.200	4.315
1964	6.921	4.900	3.977	3.592	5.148	4.315
1965	6.891	4.902	4.006	3.611	5.180	4.318
1966	6.916	4.952	3.977	3.614	4.180	4.327
1967	7.462	4.908	3.999	3.596	5.165	4.325
1968	7.501	4.948	4.000	3.606	5.180	4.302
1969	7.492	5.558	3.690	3.624	5.170	4.318
1970	7.489	5.520	3.648	3.597	5.170	4.316
1971	7.062	5.224	3.268	3.254	4.858	3.915
1972	6.843	5.125	3.202	3.226	4.743	3.774
1973	6.290	4.708	2.703	2.824	4.588	3.244
1974	5.650	4.444	2.410	2.507	4.081	2.540
1975	6.178	4.486	2.622	2.689	4.386	2.620
1976	5.788	4.970	2.363	2.457	4.127	2.451
1977	5.778	4.705	2.105	2.280	4.670	2.010
1978 (Feb.)	5.580	4.766	2.036	2.176	4.615	1.987

(a) Exchange Rate at end of period.

Line "ae" Market Rate/Par or Central Rate.

Source: International Financial Statistics: 1972 Supplement; April, 1978, Volume XXXI, No. 4, Published by the International Monetary Fund.

daily ton. Having made the comparison, it should be noted that even the Amager plant is as attractively designed.

American designers faced with local site selection resistance, may have to provide a larger aesthetics budget to even locate the plant. It would not surprise these authors to learn that the capital budget supported by 100 percent of the citizens had to be increased 20 percent so that the 3 percent of the population living near the plant site could be ameliorated and placated.

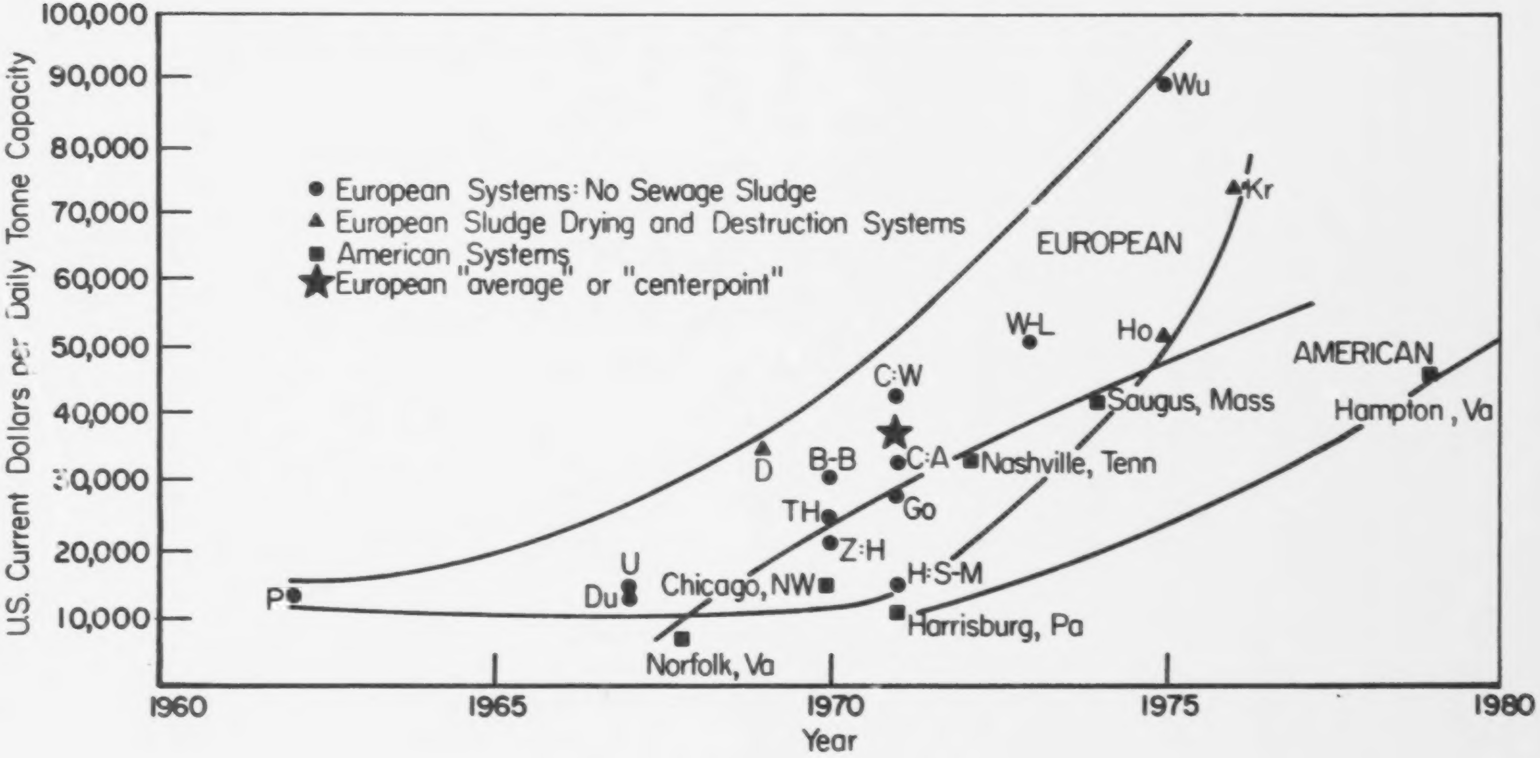
More Complex Energy Use Systems. Some newer systems maximize energy effficiency by having a back-pressure electricity turbo-generator consuming high quality steam and exhausting medium quality stream. This is then used in district heating schemes requiring miles of pipelines. As the price of energy continues to rise there will be more pressure for cogeneration and other complex capital-intensive schemes.

More Air Pollution Control Equipment. Environmental regulations have continued to tighten. The two highest capital investment cost per daily ton plants in the survey are Wuppertal ($89,582/Ton) and Krefeld ($73,905/Ton). Both plants came under the new source performance standard of the new West German regulation "T. A. Luft". In contrast to the United States, each new West German refuse burner must have a wet scrubber to collect HCl and HF gases. The Krefeld plant has a second stage scrubber to collect CO_2.

There has been minimal interest expressed so far by the other Eurpean, the Canadian and the U.S. Environmental Protection Agencies for control of HCl, HF and SO_2 from refuse burners. However, a late breaking (1978) development at the U.S. EPA may have economic consequences on this industry. The element lead (Pb) has presently been declared a "criteria pollutant". Thus in lead non-attainment areas, refuse burners may need additional expensive equipment to obtain new local permits. Frankly, it is too early to determine the final effect of the regulatory thrust.

Comparison of European, American and Co-Disposal Systems. Figure L-2 was prepared to show how the visited European mass burning systems compare with American mass burning systems. Surprisingly the American systems for the same point in time were cheaper. Envelopes have been drawn just outside of the continental distributions. Thirteen (13) out of fifteen (15) or 87 percent of the European systems rise above the American envelope. Why??? We will not pretend to precisely explain the reason for the difference. However, we have been in the American systems with the exception of Hampton, Virginia. Generally speaking we find the following differences:

1. The American systems do not have as many "bells and whistles" as the European systems.
2. The European systems have many more corrosion protection design features on their systems.
3. The American purchaser has not previously feared corrosion enough to demand protective features.
4. The American buyer concentrates more on the lowest bid while the European buyer prefers a reliable system that he and the communitycan be proud of.



COMPARISON OF EUROPEAN, AMERICAN REFUSE FIRED ENERGY AND CO DISPOSAL ENERGY SYSTEMS

FIGURE L-2. COMPARISON OF EUROPEAN, AMERICAN REFUSE FIRED ENERGY SYSTEMS

5. The European systems almost always have more aesthetic features of architecture, landscaping, conference rooms, offices, shower and locker rooms, etc.
6. There are enough systems in Europe that personnel can choose among the many plants. Decision makers believe that the aesthetics are needed to attract and hold qualified employees.
7. The essential difference, however, is momentum. With 275 systems to visit and be exposed to features, the European buyer knows and appreciates his options. To some extent, there may be peer pressures to have an excellent system. We Americans have not been exposed to enough facilities to have developed the same Continental appetite.

Of special note is that the three large co-disposal systems (Krefeld, Horsens, and Dieppe) have higher than average capital costs. Considering the accompanying eqiupment, this is understandable.

Specific Comments about the Visited System's Capital Investment

Werdenberg - Liechtenstein

The 1973 capital investment expenditures were available only in gross form as shown below:

	1973 S.Fr.	1973 U.S. $
• Refuse fired generator and building contents	13,000,000 SF	($4,007,000)
• Office and workshop-separate building and contents	1,000,000 SF	($308,000)
• Hot water distribution system	3,500,000 SF	($1,079,000)
• Steam distribution system to chemical plant	500,000 SF	($154,000)
TOTAL	18,000,000 SF	($5,548,000)

This single line 120 tonne (132 ton) per day plant thus had an investment cost per daily tonne figure of 155,548 S.Fr/tonne ($42,030/ton).

The above, however, does not include every component in the utility park. Excluded is the wastewater treatment plant, the pathological incinerator, the now closed composting plant and the general landscaping of the entire park.

The compost plant had cost about 1,000,000 S.Fr. ($231,696) in 1961. Later in 1967, the municipal waste incinerator without heat recovery (now the pathological incinerator) was built at a cost of 2,500,000 S.Fr. ($578,035).

Baden-Brugg

In 1970 this plant cost 16,400,000 S.Fr. ($3,800,000). This facility has two 100 tonne (110 ton) per day lines for a total capacity of 200 tonnes (220 tons). Thus the capital investment per daily ton capacity is 74,545 S.Fr. per tonne ($17,273 per ton). The first cost included one million S.Fr. ($232,000) for 2 electrostatic precipitators.

Duesseldorf

The first four units and associated structures built in 1965 cost 34,500,000 D.M. ($8,613,000) is shown below:

	1965 D.M.	1965 U.S. $
Mechanical equipment	15,500,000	3,869,000
Electrical	1,600,000	399,000
Structures, road, landscaping	12,000,000	2,996,000
	29,100,000	7,264,000
Construction financing over 2 years and site development	5,400,000	1,349,000
TOTAL	34,500,000	8,613,000

When the larger unit No. 5, was added within the existing building in 1972 it cost 11,800,000 D.M. ($3,864,000). Part of this proportionately higher cost was the result of a new precipitator and shredder installed at that time. The cost breakdown in 1972 was:

	1965 D.M.	1965 U.S. $
Mechanical equipment	6,500,000	2,030,000
Electrical (including precipitator)	1,770,000	553,000
Structural changes	410,000	128,000
Shredder	1,600,000	500,000
Engineering fee (2.5 percent)	220,000	69,000
Esclation cost	1,300,000	406,000
	11,800,000	3,686,000

Mr. Thoemen estimated if No. 5 were built today (1977) it would cost 20,000,000 DM ($11,800,000)* because of inflation. If all five units were built today the plant would cost 80-90,000,000 DM ($38,000,000). If No. 6 were built today in the space already available for it in the existing building with a maximum capacity of 360 tonnes/day it would cost an estimated 27,000,000 DM ($12,800,000) including a fourth precipitator and a flue-gas scrubber system for the entire plant composed of 4 scrubber modules in parallel. Mr. Thoemen's experience is that no one plant unit should be designed for more than 15 tonnes/hr, (360 tonnes/day) (396 tons/day) because of a breakdown reduces plant capacity, the accumulation in storage of more than 360 tonnes per day will rather quickly force hauling the excess to distant landfills, a fairly expensive operation.

The above costs expressed per tonne (ton) day of capacity were as follows:

	Cost D.M.	Tonne per day capacity	cost per daily tonne D.M./T	cost per daily ton $/T
1965 No. 1-4 (includes building)	34,500,000	4x240=960	35,938	15,521
1972 No. 5 (without building)	11,800,000	1x300=300	39,333	16,987
1977 If No. 6 were built (est)	Not built	1x360 360		
TOTAL	56,300,000	1,620		
1977 No. 1-5 (includes building)	85,000,000	1,260	67,460	29,134
1977 No. 5 (without building)	20,000,000	300	66,667	28,792
1977 No. 6 (4th ESP+4 Scrubbers)	27,000,000	360	75,000*	32,390 *

* Ratio is inflated by 3 extra scrubbers

Because this plant generates only high-pressure steam and not electricity, (which is then piped to a power plant 1/2 mile away) these costs are low for most plants of this size which do have the equipment to generate electricity. It appears that the German requirement for removal of HCl and HF by means of scrubbers will raise plant costs substantially. Also until some large scale scrubber systems demonstrate reliable operation the need for new system flexibility to cope with problems such as corrosion, plugging and acid mist emission will tend to increase costs.

The land area required for this operation is as follows:

Structures	7,000 m^2
Landscape	8,000 m^2
Roads	15,331 m^2
	30,831 m^2 (331,862 ft^2)(7.5 acres)

The value of this property is estimated in 1977 terms as 7,700,000 D.M. ($3,658,000). It is of considerable significance that if this same expensive industrial property were utilized as a sanitary landfill, it would have become filled in about 2 or 3 years at the average rate this plant is now operating (290,000 tonnes/yr or 319,000 tons/yr).

Wuppertal

The plant cost 126,000,000 D.M. ($48,055,000) in 1975.

Table L-3 shows the distribution of construction and equipment expenditures up to December 31, 1975, when the plant was nearly completed but not yet operational. Construction work on the scrubber system was still underway during the plant visit in May 1977.

The land was previously owned by the city and was valued at 10,000,000 D.M. ($3,900,000).

TABLE L-3. STATUS OF CONSTRUCTION EXPENDITURES-WUPPERTAL - AS OF DECEMBER 31, 1975

	Deutsch Marks	Thousands of Dollars at DM 2.27/$
Buildings, structures	530,678.82	233
Planning -- Kesselwerke	1,196,223.05	526
Main contract with Vereinigte	54,400,000.00	23,980
Advance payments to Vereinigte	1,007,121.20	443
Excavation - foundation	2,154,521.80	948
Turbine I - 1.5 km	2,686,816.17	1,182
Transformer - power line	3,305,595.40	1,454
Feedwater tank	149,109.73	66
Residue crane	236,991.87	104
Weigh scale	937,780.18	413
Offices, office equipment	240,379.49	106
Supporting walls (required on hillside site)	2,521,616.57	109
Scrubbers	4,619,810.24	2,033
Miscellaneous	123,613.24	54
Air-cooled condenser II	2,110,150.84	928
Turbine II	2,008,323.89	884
Landfill	84,120.65	37
Total Construction as of December 31, 1975	71,312,853.14	34,458
Construction Interest Payments		
Interest to Vereinigte Kesselwerke	5,240,600.00	2,306
Interest on other loans	2,289,121.68	1,007
Miscellaneous interest	233,336.72	103

TABLE L-3. (Continued)

	Deutsch Marks	Thousands of Dollars at DM 2.27/$
Premiums	158,470.00	70
Sub-total	7,921,528.40	3,485
Total expenditures through December 31, 1975	86,234,381.54	37,943
Total estimated final cost of completed plant	126,000,000.00	55,440
Estimated final cost per daily tonne of capacity	87,500 (DM/tonne)	42,350 ($/ton)

Source: Translated from 1975 Financial Report of MVA Wuppertal GMBH, March 1977.

Krefeld

The plant cost 60,000,000 D.M. ($25,391,451) in 1976.

Paris:Issy

The Paris:Issy-les-Moulineaux plant was built in 1962 for 110,000,000 Fr ($22,450,000). The plant was built on the previous Issy incinerator site so the land cost nothing. Roughly 600,000 Fr fr ($122,000) was spent to tear the old plant down and level the area.

Hamburg:Stellinger-Moor

The Hamburg:Stellinger-Moor plant cost about 49,000,000 D.M. ($15,000,000). The construction begun in 1970 was completed in 1972.

Zurich:Hagenholz

The first two units and the administration, social, truck repair, truck storage, bicycle storage, and space parts areas were built in 1969 at a total cost of S.Fr. ($12,969,000). Of this total about 45,694,000 S.Fr. ($10,582,000) was for the refuse fired steam generator (RFSG) building itself. Von Roll's chute-to-stack price was 23,000,000 S.Fr. ($5,327,000). Later, in 1973, an additional 14,000,000 S.Fr. ($4,316,000) was spent for Unit No. 3 and water deaeration. Out of this, the Martin chute-to-stack contract was 11,430,000 S.Fr. ($3,523). This bring the total for all three RFSG units to 59,700,000 S.Fr. ($13,826,000)

Details of the first Von Roll construction period are shown in Table L-4. Similar details for the last Martin construction period follow in Table L-5. Such detail is shown so that planners will have a broader scope of what may need to be included when project planning. Perhaps the 100,000 S.Fr. ($23,159) European style bicycle house line item will remind an American planner to allocate funds for, as an example, an automobile parking structure.

The Hague

The capital cost for the plant as it stands today, not including land cost, was 62,000,000 Gl. ($18,520,000). This includes Units 1-3, and the entire building for 45,000,000 Gl. ($12,500,000) built in 1967-68. This also includes Unit 4 added within that building in 1972-74 at a cost of 17,000,000 Gl. ($6,020,000).

Dieppe

The general contract in 1969 for building the refuse plant structure without equipment or land was for 1,532,771, F.Fr. ($276,000). The installed equipment including the sludge dryers raised the total refuse plant cost to 6,400,000 F.Fr. ($1,151,000).

TABLE L-4. CAPITAL INVESTMENT COST (1969) FOR UNITS #1 AND #2 AND OTHER BUILDINGS AT ZURICH:HAGENHOLZ

	Total Complex (SF)	RFSG Only (SF)
Building costs (excavation, foundation, structure, stack,...)	11,000,000	11,000,000
Equipment (Von Roll contract chute to stack) (2 boilers, 2 furnaces, ...)	23,000,000	23,000,000
Outfit	20,000	20,000
Administrative building	2,500,000	1,250,000
Workshop	2,200,000	440,000
Trucks-garage	700,000	--
Connection-way (alley)	1,200,000	--
Scale house	350,000	350,000
Bicycle house	100,000	50,000
Schuttung (?) Tahr (?)	750,000	375,000
Environment (garden, fences,...)	600,000	300,000
Streets and parking places	1,300,000	650,000
Oil storage tank	115,000	115,000
Others		
Land*		
Construction management fee		
Engineering fees		
Interest during construction		
Others Total	12,000,000	8,144,000
Capital Investment	59,700,000	45,694,000

*(SF 6,000,000 value of land previously purchased)

TABLE L-5. CAPITAL INVESTMENT COSTS (1972*) FOR UNIT #3 AND THE WATER DEAERATION TANKS AND ROOM AT ZURICH:HAGENHOLZ

Furnace and boiler (Martin contract chute-to-stack)	11,430,437 S.F.
Spare parts**	11,374
Deaeration tanks (2)	339,837
Foundation work	548,281
Piling	43,894
Temporary office building	17,776
Scaffolding rental	9,415
Demolition and boring	96,242
Front wall, trusses, insulation	95,734
Steel structure	110,574
Heating/cooling/electrical/plumbing	125,628
Inside finishing	97,767
Miscellaneous	43,323
Photography and brochures	6,294
Engineering fee	107,453
Architect fee	58,373
Other expert fees	1,605
Interest during construction	800,015
Water treatment room	62,314
Total Capital Investment for Unit #3	14,006,335 S.F.
Reserve	650,000
Minderkosten (working capital?)	521,665
Total Amount Financed	15,178,000 S.F.

*75% of the capital costs were paid in 1972.

**However, the spare parts inventory stored in the basement under the truck repair garage now totals about SF 1,000,000.

From the time the tender was made in 1969 until the plant was commissioned in 1970, the final price was up about 16 to 18 percent because of inflation.

M. Marchand reported that the wastewater treatment plant cost 4,980,000 F.Fr. ($896,000).

In 1971, additional purchases were made of a second crane, weigh station, furniture, ash truck, refuse containers and workshop and tools for about 750,000 F.Fr. ($247,000)

In summary, the plant cost 13,663,000 F.Fr ($2,564,000) as shown below:

	1971 F.Fr.	1971 U.S. $
Land	No Charge	No Charge
Excavation and Structure	1,533,000	276,000
Chute to Stack (including sludge driers)	6,400,000	1,151,000
Wastewater treatement plant	4,980,000	890,000
Extras bought 2 years later	750,000	247,000
	13,663,000	2,564,000

Gothenberg

Construction of the Savenas plant, which was completed in 1971, cost about 98,000,000 S.Kr. ($20,173,000) not including the cost of land which is leased for 105,000 S.Kr. ($22,000)/year . The rest of the waste handling system, including the transfer stations, the new Tagene landfill, and the 30 transfer trucks, cost an additional 22 million S.Kr. ($4.5 million).

Uppsala

The costs of the various stages of construction of the Uppsala waste plant were approximately as follows:

	Varying Years S.Kr.	Varying Years U.S. $
Years1960 Furnaces 1 & 2 by Kochum-Landsverk and Boiler 1	3,400,000	$ 656,000
1965 Furnace 3 by Kochum-Landsverk and Boiler 2	1,000,000	193,000
1970 Furnace 4 by Brunn & Sorenson and Boiler 3	4,000,000	774,000
1970 New Crane	150,000	29,000
1970 Precipitators	1,300,000251	
1970 Bulky Waste Shear	200,000	39,000
1170 New Ramp to Increase Bunker Depth	1,000,000	193,000
TOTAL	11,050,000	2,135,000

The plant operating management estimates that replacement in 1977 of the whole system would cost about 60 million S.Kr. ($12.8 million).

In 1973, the original chimney was replaced at a cost of about 1 million S.Kr. ($218,000).

Horsens

The hot water generating plant was built in 1973-1974 as a turn key project within the contract price which was composed of the following:

	1973 D.Kr.	1973 U.S. $
Equipment, installed	4,634,152	$736,749
Sprinkler flue gas cooling system	85,315	13,564
Building including stack	3,639,800	578,665
Weighing scale	113,900	18,108
Rotary sludge dryer, installed	1,795,406	285,438
Garage	525,850	83,600
Miscellaneous: fence, landscape, roads	300,000	47,695
TOTAL CONTRACT COST	11,094,423	1,763,820

The building and stack are large enough to accomodate a second unit. This total cost results in a capacity cost for the 5 tonne/hr unit of 92,454 D.Kr./daily tonne of capacity ($13,362/ton). Compared to some steam generators, this cost is very low.

Subsequently, in 1976-1977, the hot water boiler and transmission pipe were built so that the Horsens plant would also supply energy for district heating. The following are additional costs:

	1976 D.Kr.	1976 U.S. $
Boiler, installed	1,750,000	$ 302,000
Building modification	85,000	15,000
Sludge centrifuge, dryer changes	998,600	173,000
Building work	120,000	21,000
Circulation pump, tank, for district installed	190,000	33,000
New pump building at district plant	724,000	125,000
Hot water transmission line, 1.8 km	1,700,000	294,000
Project supervision	221,000	38,000
Building changes at Dagnas heating	200,000	35,000
SUBTOTAL	5,988,800	1,054,000
Pipeline from satellite station to plant	740,000	104,000
Project management	96,200	17,000
Booster station	75,000	13,000
Extras, estimated	208,544	36,000
TOTAL COST	7,108,544	1,224,000

Adding this cost, 7,108,544 D.Kr. ($1,224,000), the original plant cost brings the total waste-to-energy plant cost to 18,202,967 D.Kr. ($2,987,820). Based on a daily rated capacity of 120 tonnes/day, this is a capital cost rate of 151,691 D.Kr./tonne/day ($24,899/ton/day). This cost is also comparatively low considering that the pipeline and other costs are included. A major factor in keeping the costs down is the use of a low-pressure, firetube water-heating boiler instead of a high-pressure, water-tube, steam boiler that would be required if power were to be generated.

Copenhagen:Amager

The refuse-fired hot water generating plant itself cost 117,600,000 D.Kr. ($16,652,000) during the 1969-1970 construction period. The original capital costs were as follows:

Ground Work and Construction	63,000,000	$8,412,000
Machinery	45,000,000	6,009,000
Other Cost	9,600,000	1,282,000
TOTAL	117,600,000	15,703,000

Since then, another 40 million D.Kr. ($5.6 million) has been spent on capital improvements. Both assets and liabilities, by definition, equal 181,452,000 D.Kr. ($25,694,000). At $64 tonnes per day the cpaital cost per tonne is 210,000 D.Kr./tonne ($27,035/ton).

The 1975-1976 annual report presents an accounting schedule of assets and a schedule of liabilities. These are shown in Table L-6.

Copenhagen: West

The original three-furnace complete plant cost 140,580,022 D.Kr. ($18,764,000) in 1970-1971. With the addition of the fourth unit in 1975-1976 and some other items as outlined in Table L-7 the grand total capital investment cost is 204,972,634 D.Kr. ($33,178,000) against 864 tonnes per day, the cpaital cost per tonne is 237,237 D.Kr/tonne ($30,539/ton). This table shows the capital investment cost distributed both by assets and liabilities.

General Comments About Expenses

Detailed expenses where available, have been displayed on Tables L-8 and L-9. Table L-9 presents a summary of the raw data from Table L-8.These numbers are provided with the recommendation that they be used cautiously. They are the outgrowth of various accounting procedures. There are many empty cells in the table where data was not available in a usable fashion. For further detail, the reader is referred to the later plant-by-plant discussion.

Because there are blank cells in the tables, the average of the total expenses does not equal the sum of the average expense components. In 1976, the average plant surveyed processed 195,790 tonnes (215,369 tons) per year or 536 tonnes (590 tons) per day. The average total expenses were $27 per ton.

TABLE L-6. ASSETS AND LIABILITIES OF COPENHAGEN:AMAGER AS OF MARCH 31, 1976

ASSETS

Current Assets (Cash, Stocks, Supplies)			12,882,000 Dkr
Money on Loan to Others			2,431,000
Transfer Station			8,980,000
Landfill			1,625,000
Refuse Burning Hot Water Generator*			155,534,000
Under Surplus, 1972-1973		4,339,000	
Over Surplus, 1973-1974	1,757,000		
Over Surplus, 1974-1975	489,000		
Over Surplus, 1975-1976	2,093,000	4,339,000	
TOTAL ASSETS			181,452,000 Dkr

* Includes 7 years of improvements.

LIABILITIES

Loan on Refuse Fired Hot Water Generator	101,920,000 Dkr
Loan on Landfill	108,000
Short Term Creditors	2,538,000
Accrual Account for Waste Materials Experimentation (?)	60,000
Accrual Account for Plant Workers That Have Left (Retired ?)	35,000
Accrual Account for Renewal of Ash Transportation Plant (?)	1,566,000
Accrual Account for Interest and Capital Return	34,927,000
Equity in the Refuse Burning Plant	39,718,000
Equity in the Transfer Station	580,000
TOTAL LIABILITIES	181,452,000 Dkr

Table L-7. CAPITAL COST (ASSETS AND LIABILITIES) AT COPENHAGEN:WEST (FISCAL YEAR 1975-1976)

Assets	D.kr.	Liabilities	D.kr.
Reserve amount held in quick asset form to pay for the establishment of a fourth furnace, district heating plant, and for the coverage of cost outlays	50,013,257	The amounts, which are free from part-payment until 1979/1980 are subject to an annual interest of 8 percent, and the debt of West incineration to these townships, on March 31, 1976	24,071,789
Amount due from townships, and other debtors	2,880,171	Outside capitals from various creditors amount on March 31, 1976	106,365,615
Storeroom material, oil and cafeteria material	254,203	Amount concerning guarantees with enterprises (sureties)	2,480,581
Fixed plant in place	140,580,022	Difference between the face value and the quoted value (? market value) of obligation bought	12,672,616
Expenses (?)	16,224	SUBTOTAL	145,590,601
Sum of part to establish a slag landfill at Vestskoven	1,864,009	Amsuat (variance creditors other than West incineration; that is, tax to the source from staff members, due vacation compensation, etc.)	506,758
Preliminary investigations for the establishment of a dumping ground at Vestskoven	44,552	Current account with customs concerning (name ?)	2,270,282
Sum paid out for the fourth furnace	2,077,213	Area of expenses	10,303,313
Sum paid for the second crusher	1,436,420	Creditors	13,080,353
Investment sum for the transfer station of Hillerod, where West incineration, as agreed, has established the machine plant as well as different other lessor installation operations	132,365	Investments (or sums placed aside)	6,577,225
Investment sums for the establishment of district heating plants to Ll. Birkholm, etc., on March 31, 1976	5,674,198	Township Capitals	39,724,455
TOTAL ASSETS	204,972,634	TOTAL LIABILITIES	204,972,634

TABLE L-8. DETAILED EXPENSES FOR 15 EUROPEAN REFUSE TO ENERGY SYSTEMS (U.S. 1976 $ PER TON)

	Operating Labor	Other Operating Expenses	Total Operating Expenses	RFSC Maintenance	Energy Distribution Line Maint.	Other Maint.	Total Maint. Expenses	Residue Disposal	Insurance	Admin-istration	Transfer Station Expenses	Air Pollution Control Testing & Verification
Werdenberg-Liechtenstein	8.59	4.47	13.06	1.46		0.18	1.64	1.84	1.08	0.19		
Baden-Brugg	8.31	1.28	9.59	0.79		0.10	0.89	1.47	0.43	0.13		
Duesseldorf	3.16	1.78	4.94				4.92	0.15	0.15	0.37		
Wuppertal												
Krefeld												
Paris:Issy	2.62						4.02	0.29		1.50		0.57
Hamburg:Stellinger-Moor												
Zurich:Hagenholz								2.28	0.20	0.52		
The Hague			3.73				6.15	1.12				
Dieppe												
Gothenburg								0.27		3.09		
Uppsala										0.98		
Horsens												
Copenhagen:Amager	3.10	1.35	4.45				1.49	0.99		0.58	2.47	
Copenhagen:West	3.20	1.84	3.04	1.09	0.85	—	1.93	0.80	—	0.91	—	—
	4.83	2.14	6.80	1.11	0.85	0.14	3.01	1.02	0.47	0.92	2.47	0.57

TABLE L-8. (Continued)

Training & Safety	O & M Plant Labor Total	O & M Services & Material	Overhead	Gov't Taxes & Fees	Value Added Profit	Other Expenses	Interest on Loans	Depreciation or Amortization	Principal and Interest	Contribution to Reserves	Total Expenses	Tonnes
						1.22	11.57	24.04	35.61		54.64	26,018
						0.02	3.40	4.98	8.38	4.34	25.25	41,693
						0.89			8.10		19.52	297,359
												178,000
												114,000
0.10						1.10						588,904
	10.03	3.49	1.43			2.50(?)	7.50	3.51	11.01		28.47	420,680
	3.31	0.75				1.54	3.93	11.38	15.31		23.91	223,595
									10.43		21.43	229,000
					2.37	14.41						14,892
	3.11	4.05				9.01(?)	5.62	2.36	7.98		27.51	242,536
	4.62	5.47							6.55	1.81	19.43	52,040
												18,909
				0.63			4.57	4.93	9.50	2.25	22.36	255,000
—	—	—	—	0.68	—	0.17	6.25	8.62	14.87	3.64	28.04	234,230
0.10	5.27	3.44	1.43	0.65	2.37	3.43	6.12	8.55	12.77	3.01	27.06	2,936,856 ÷ 15 = 195,790

TABLE L-9. SUMMARY OF EXPENSES FOR 15 EUROPEAN REFUSE TO ENERGY SYSTEMS

	1976 U.S. Dollars per Short Ton											Expenses Without Interest, Depreciation And Contribution To Reserve	
	Operations & Maintenance Labor & Materials	Residue Disposal	Admin-istration	Insurance and Taxes	Misc. Expenses	Interest and Depreciation	Contribution to Reserves	Total Expenses	Year Operations Began	Tonnes Per Year	Total Expenses U.S. $	Total	Per Ton
Werdenberg-Liechtenstein	14.70	1.84	0.19	1.08	1.22	35.61	0.00	54.64	1974	26,018	1,564,786	495,000	14.03 a
Baden-Brugg	10.48	1.47	0.13	0.43	0.02	8.38	4.34	25.25	1970	41,693	959,000	522,000	12.52
Duesseldorf	9.86	0.15	0.37	0.15	0.89	8.10	0.00	19.52	1965-72	297,359	6,385,000	3,396,000	11.42
Wuppertal									1976	178,000			
Krefeld									1976	114,000			
Paris-Issy	6.04	0.29	1.50		1.10				1965	588,904		5,612,000	9.53
Hamburg-Stellinger-Moor	14.95				2.50	11.02	0.00	28.47	1972	420,680	13,174,000	7,341,000	17.44 b
Zurich-Hagenholz	4.04	2.28	0.52	0.20	1.56	15.31	0.00	23.91	196 -73	223,595	5,881,000	1,923,000	8.60
The Hague	9.88	1.12				10.43	0.00	21.43	1968-71	229,000	5,398,000	2,519,000	11.00
Dieppe									1974	14,892			
Gothenburg	7.16	0.27	3.09		9.01	7.98	0.00	27.51	1970	242,536	7,339,000	4,737,000	19.53 c
Uppsala	10.09		0.98			6.55	1.81	19.43	1970	52,040	1,009,000	576,000	11.07
Horsens									1974	18,909			
Copenhagen-Amager	5.94	0.99	0.58	0.63	2.47	9.50	2.25	22.36	1970	255,000	5,641,000	2,706,000	10.61
Copenhagen-West	6.97	0.80	0.91	0.68	0.17	14.87	3.64	28.04	1970	234,230	6,287,000	2,232,000	9.53
AVERAGE ($/ton)	9.16	1.02	0.92	0.53	2.10	12.77	1.20	27.06	1971	195,790	5,361,779	2,914,455	12.75
Divisor "N"	11	9	9	6	9	10	10	10	15	15	10	11	11
PERCENT (%)	33.85	3.77	3.40	1.96	7.76	47.20	11.12	109.062*					

* The sum of the average percentages cannot equal 100,000 percent until all of the data cost cells are filled.

a. Unusually high interest and depreciation and O & M

b. Unusually high labor costs

c. Includes 5 transfer station operations

There should be no doubt about the capital intensive nature of refuse fired steam and hot water generators. Operations and maintenance accounts for slightly over a third of total costs.

The numbers have been recalculated a second time without the very small Werdenberg-Liechtenstein plant (a single 120 tonne/day line) data. Not using this data point reduces the total expenses to $24,33 per ton in 1976.

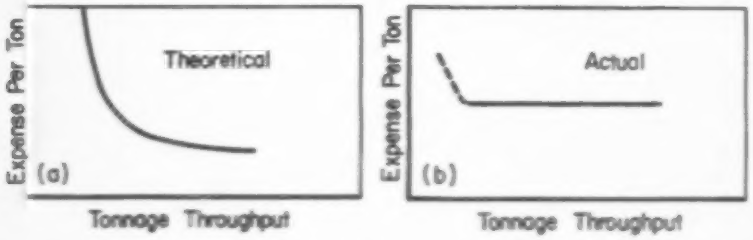
Economics of Scale

While conducting the interviews, these researchers began to feel that there were no economics of scale in these wastes-to-energy plants. With the Werdenberg-Liechtenstein excepton, there seemed to be no effect of plant capacity on total expenses per ton of refuse processed.

With this suspicion, Figure L-3 was generated showing total expenses per year versus annual tonnage. The data appeared to be linear. Deviations from the straight line were easily explainable in each facility. Deviations were explainable in reasons shown in the figure.

To plot the same information but in a different manner, Figure L-4 was constructed showing U.S. $ expenses per ton versus the annual tonnes throughout. Excluding Werdenberg-Liechtenstein, only a straight horizontal line could be drawn through the points.

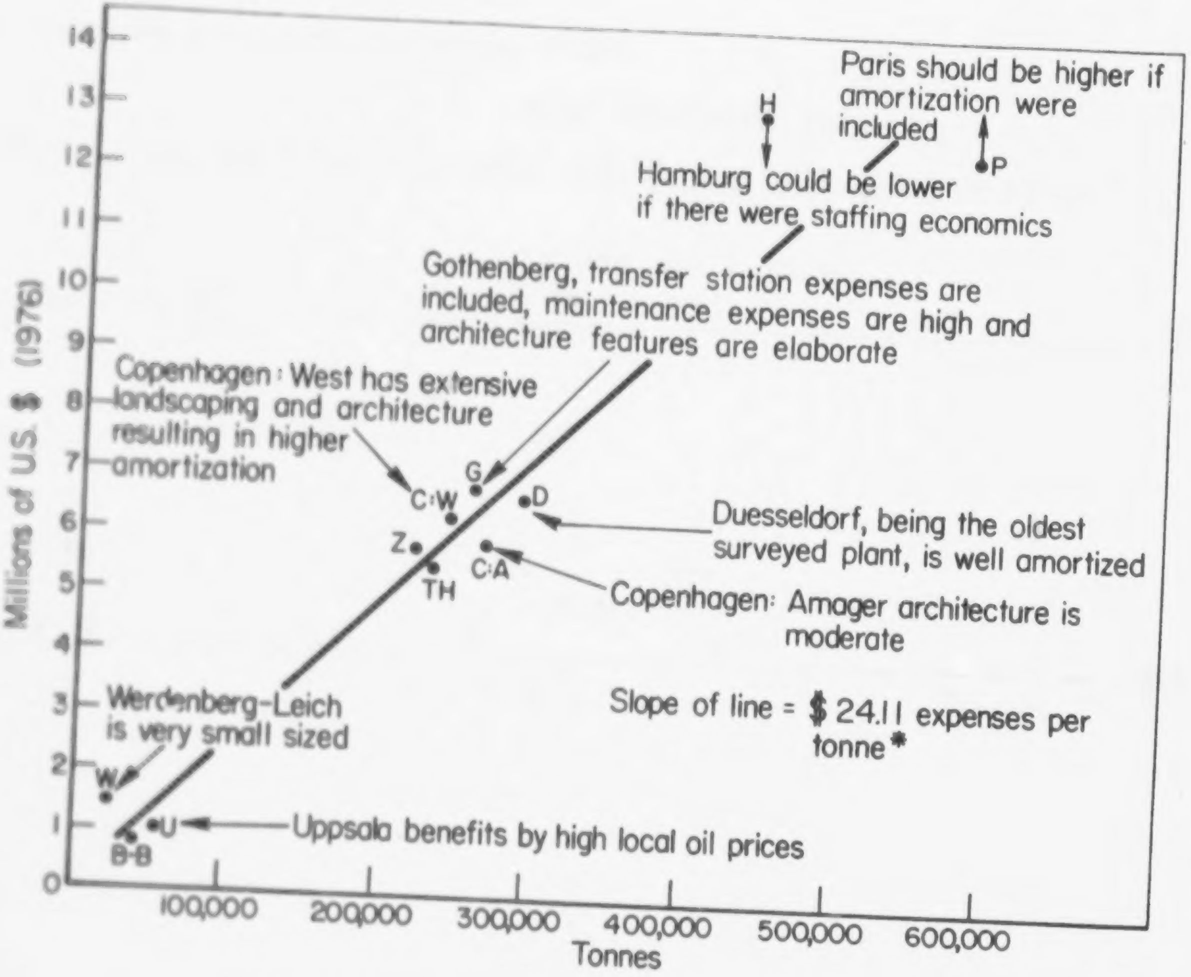
Conventional economics of scale theory is represented by the below graph (a). This compares with the actual of graph (b).



ECONOMIES OF SCALE

Reasons for this observation have perplexed these researchers. The reason seems to be in the thought and action patterns of customers, vendors egineers, designers, architects - the patterns of those who specify the system. We have observed that the bigger the system, the more "bells and whistles" are added. A common attitude was, "We were building a bigger plant so we could afford to do things the right way". In contrast, "Our plant was so small that we had to take advantage of every efficiency generating option available." Some specific examples are given below:

1. The small Baden-Brugg plant has no shear or shredder
2. The large Duesseldorf plant has both a shear and a shredder
3. The medium sized Copenhagen and Gothenburg plants have elaborate conference rooms
4. The smaller plant operators walk to the furnace to see how the fire is as the primary mmeans of controlling operations
5. Martin, in its larger furnaces, not only uses a analog computer "black box" to variably control feed rate but they



TOTAL ANNUAL EXPENSES VERSUS ANNUAL TONNAGE

*Excludes High Werdenberg-Leichtenstein number

FIGURE L-3. TOTAL ANNUAL EXPENSES VERSUS ANNUAL TONNAGE

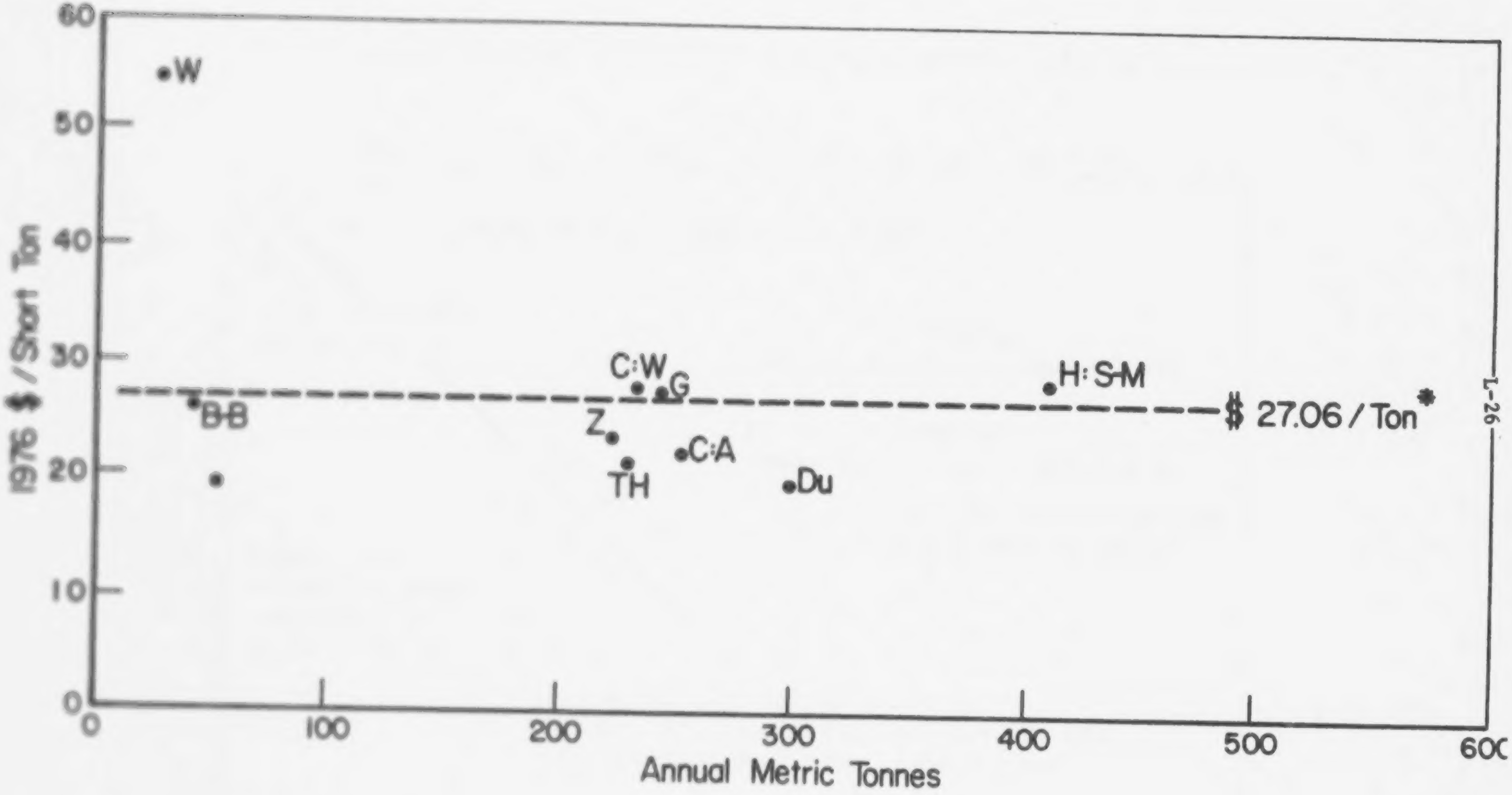


FIGURE L-4. EXPENSES PER TONNAGE (U.S. $ PER TON) VERSUS ANNUAL TONNES (1976 EXCHANGE RATE)

*Includes High Werdenberg—Leichtenstein number also install an attemperator between the first and second stage superheater to control exit steam temperature to 400 C to 5 C.

6. At Werdenberg-Leichtenstein, the plant manager and his wife do all the office work, correspondence and bookkeeping
7. Yet at Hamburg, there is a staff of office workers at the plant and a cadre of people at the city's central office.

The above are not made as particular criticisms but rather seem to be as observations about human nature. It seems that an operating cost between $18 and $30 per ton is the acceptable target.

General Comments About Revenues

Detailed revenues are presented in Table L-10. The previously mentioned cautions about expense data hold true for revenue data as well. Similarly Table L-11 shows the Summary of Revenues. To permit data comparisons, total Expenses are defined to equal total Revenues. Thus theoretically Table L-10 and Table L-11 should have equal expense/ton and revenue/ton figures. However, the average is different: $27.40/ton expenses and $28.43/ton revenues because the plants used in calculating the average are different.

As a gross summary, Table L-12 has been prepared.

TABLE L-12. **GROSS SUMMARY OF REVENUE FROM EUROPEAN REFUSE FIRED ENERGY PLANTS**

	All Plants*		Without Werdenberg-Liechtenstein	
	$/Ton	%	$/Ton	%
Net disposal cost or tipping fee	18.83	59.4	16.38	55.4
Sale of energy (hot water, steam, electricity)	7.38	23.3	7.51	25.4
Sludge destruction credit	3.12	9.8	3.12	10.6
Interest on reserves	1.07	3.4	1.07	3.6
Other revenues	0.91	2.9	1.02	3.5
Sale of scrap iron and road ash	0.39	1.2	0.44	1.5
Average of Revenues	28.43	100.0	25.81	100.0

*Where adequate data is available.

Sale of Energy

AS a general of thumb, American refuse (household, commercial and light industrial waste) will produce a net salable 5,000 pounds steam per ton of refuse while European refuse produces a lower amount, perhaps 4,000 pounds steam per ton of refuse. The sale of energy revenue of $7.51 per ton can be converted to $1.88 per million. Many persons have commented that the key reason that the Europeans have developed their refuse-fired energy systems is that the price of energy in Europe was much higher than in the U.S. While this may been true when the European plants were initially planned, by 1976 incremental U.S. energy prices were close to European prices.

TABLE L-10. DETAILED REVENUES OF 15 EUROPEAN REFUSE TO ENERGY PLANTS (U.S. 1976 $ PER TON)

	Sale of Compost	Sale of Scrap Iron	Sale of Sand Ash	Waste Oil Processing	Sale of Hot Water	Sale of Steam	Sale of Electricity	Indust. & Private Tip Fee	Other Community Tip Fee	Home Community(ies) Tip Fee	Head Tax	Rentals & Leases	Interest on Reserves	Other	Sludge Destruction Credit	Transfer Station & Landfill Receipts	Total
[illegible]	0.04	0.14		0.58	← 1.94	→	0.86				48.75			0.05			54.64
Baden Brugg							6.17				18.63	0.11	0.02	0.32			25.25
Duesseldorf		1.15	0.05			9.47 →	→				8.84						19.52
Wuppertal		←	0.58				7.56				35.66						43.80
Krefeld											(The new plant's economic data was not available)						
Paris Issy		←	0.26			6.25 →	→				6.27	(The total is not comparable because amortization is left out of the expense equation)					
Hamburg Stellinger Moor							5.92				22.55						
Zurich Hagenholz		0.03				0.39	1.72	3.67		6.69	2.30	0.11		1.03			23.91
The Hague							5.59	2.35	1.12		12.37						21.43
[illegible]																	
[illegible]					8.17			←		→	19.36						27.51
[illegible]						11.70		←		→	6.83						18.53 (1976)
[illegible]					9.37			2.89	1.06		11.26				3.12		27.70
Copenhagen Amager					3.80			1.59		4.05	10.13	0.15	0.63			2.01	22.36
Copenhagen West	—	0.23	—	—	6.70	—	—	1.36	—	5.20	11.59	—	2.58	0.13	—	0.25	28.04
	0.04	0.39	0.30	0.58	6.01	6.95	5.62	2.37	1.09	5.58	16.46	0.12	1.08	0.39	3.12	1.13	28.43

(1) The new plant's economic data for 1976 was not available at Krefeld.

(2) The total is not comparable because TIRU operates the plant, but the City of Paris owns the plant. Amortization is left out of the expense of operation. Hence, costs revenues are not collected and a total of given figures would be misleading.

(3)

(4)

TABLE L-11. SUMMARY OF REVENUES FROM 15 EUROPEAN REFUSE TO ENERGY PLANTS (U.S. 1976 $ PER TON)

	Sale of Scrap Iron and Road Ash	Sale of Energy*		Net Disposal Cost on Tipping Fees	Interest on Reserves	Sludge Destruction Credit	Other Revenues	Total Revenues
Werdenberg-Liechtenstein	0.14	5.80	W,S,E	48.25			0.45	54.64
Baden-Brugg		6.17	E	18.63	0.02		0.43	25.25
Duesseldorf	1.21	9.47	S,E	8.84				19.52
Wuppertal	0.58	7.56	E	35.66				43.80
Krefeld						?		
Paris:Issy	0.26	6.25	S,E	6.27				
Hamburg:Stellinger-Moor		5.92	E	22.55				
Zurich:Hagenholz	0.02	10.11	S,E	12.66			1.12	23.91
The Hague		5.59	E	15.84				21.43
Dieppe						?		
Gothenburg		8.17	W	19.34				27.51
Uppsala		11.70	S	6.83				18.53 (1975)
Horsens		9.37	W	15.21		3.12		27.70
Copenhagen:Amager		3.00	W	16.57	0.63		2.16	22.36
Copenhagen:West	0.15	6.78	W	18.15	2.58	—	0.38	28.04
TOTAL	0.39	7.38	W,S,E	18.83	1.07	3.12	0.91	28.43

*W: Hot Water, S: Steam, E: Electricity.

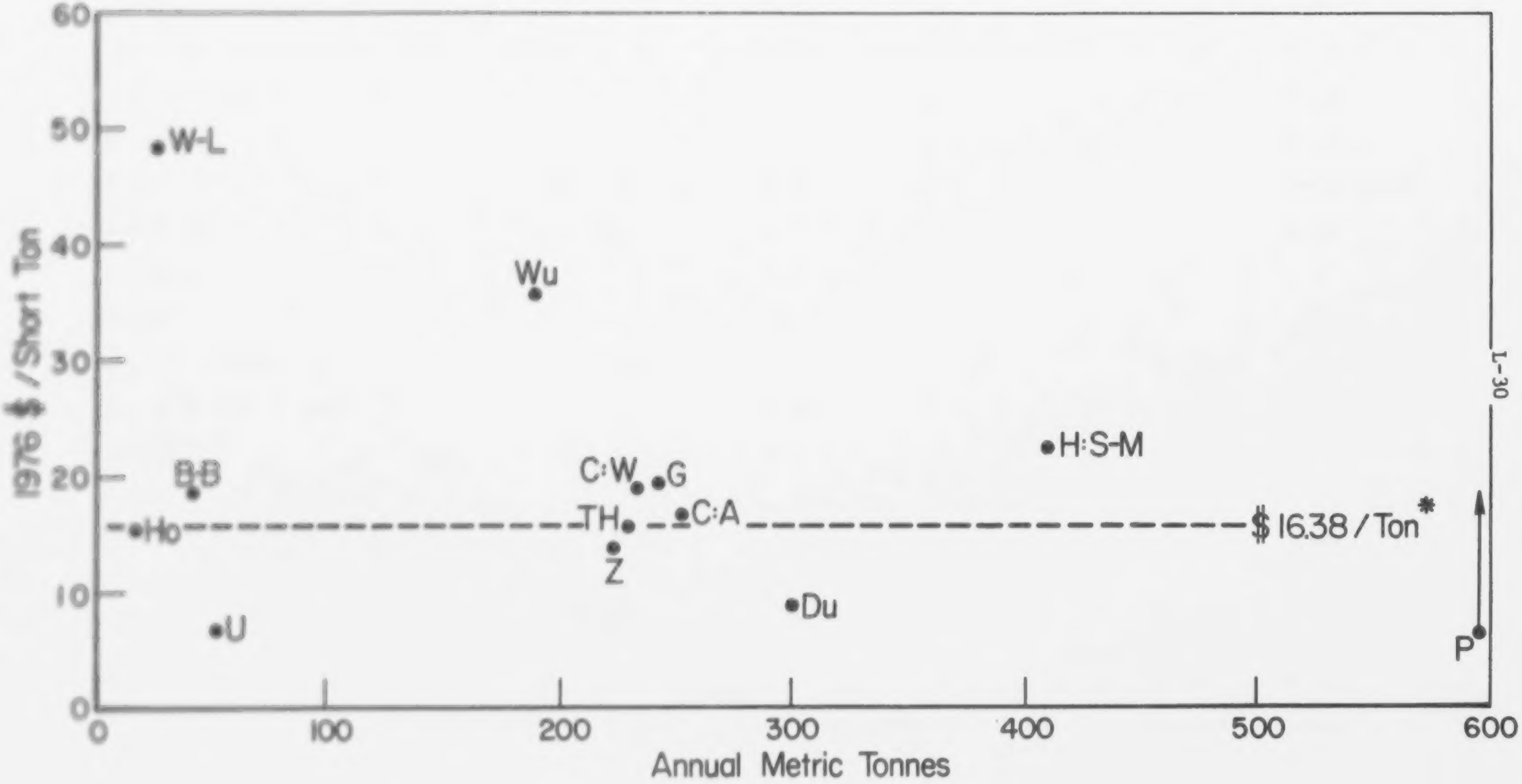


FIGURE L-5. NET DISPOSAL COST OR TIPPING FEE AT 13 EUROPEAN REFUSE FIRED ENERGY PLANTS

*Excludes High Werdenberg–Leichtenstein number

Sludge Drying Credit

Of 30 refuse burning systems that Battelle researchers visited, use the energy in the refuse to dry and/or destroy sewage. However, only at Horsens do we have a clear and separably reported sludge drying credit -- a figure of $3.12 per refuse input ton.

Sale of Scrap Iron and Road Ash

Ash residue is sold not only for revenue but also to eliminate or reduce the ash disposal landfill expense. Therefore the decision maker should add potential metal scrap and road aggregate revenue to the marginal savings when less ash is landfilled.

Unfortunately we do not have enough economic data to conclude that ash recycling is marginally beneficial or otherwise for the average plant. Where the refuse burning plant is located in a steel producing region that needs scrap for a melt or there is a shortage of conventional road aggregate products the economics should be more attractive.

Interest on Reserves

In a few systems more money is collected than spent. This results in Contribution to Reserves which is akin to profit in a private enterprise system. This figure is added to other expenses so that total expenses equal total revenues. This adding of "profit" to expenses is necessary to permit comparisons among these varying plants with varying accounting systems.

On the revenue side, interest on these previously collected and invested reserves is added in revenues. In a few systems, this figure is surprisingly high. When averaged over the four reporting plants, the average is $3.01 per ton. But when averaged over ten plants, the average is $.91 per ton.

While mentioning "profit", we must be careful. Another way to view the number is to consider that this public organization, owned by taxpayers, overcharged themselves. The extra recovery can:

- be invested to produce interest revenue which reduces net disposal costs
- be applied to dept reduction
- provide a cushion for future losses
- build a fund for addition of a new line or replacement of the entire facility.

Net Disposal Cost or Tipping Fee

To use a business expression, the "bottom line" is the Net Disposal Cost or Tipping Fee. This is the resulting cost or burden borne by the citizens, taxpayers and generators of waste. This is the figure used to compare techinial alternatives solid waste disposal (compost, landfilling, materials recovry, waste-to-energy, etc.).

This ranges upward from a low of $6.27 per ton at Paris: Issy. However, this is not truly a comparable figure because there is no depreciation expense shown since the plant is owned by the city of Paris. Had normal depreciation and interest been included the net disposal cost would be well over $10 per ton.

Uppsala, a refractory walled unit, (and not a water-tube wall) shows the best net cost at $6.83 per ton for two reasons. First, three of the furnaces are old so the original capital investment cost to amortize is small. Perhaps some equipment may be fully depreciated already. Then too, many claim that original capital cost on the simpler refractory walled low temperature energy systems are inherently lower than the complex water tube wall-high temperature steam systems requiring expensive corrosion protection.

Second, in addition to having the lowest amortization costs, Uppsala has the highest energy revenue per input ton $11.70, of any visited system. This is due to the revenue formula that parallels the cost of foreign oil, storage costs, 50 mile transport costs and Swedish taxes. The Swedes, not having national energy sources, have traditionally paid more for their energy.

It is interesting to compare at this point this "best" financial result system in our survey with the U.S. system having the lowest net cost. The Babcock and Wilcox - Detroit Stoker system in Nashville, Tennessee sells energy at about $35 per refuse input ton. As a result, the tipping fees need only be $.50 per cubic yard or about $2.00 per ton. The reader is cautioned not to overemphasize the Nashville results because of the unique circumstances[*] of its development, operating history, government customers, financing, promise to local taxpayers, etc.

Comment should be made on the three highest net cost systems. Werdenberg-Liecetnstein's $48.25 per ton is the highest by far. The vendor knew that the figure would be high and so stated to the community. The community, however, considered its scenic beauty too great to mar with another landfill. In addition, there was a most attractive Swiss federal grant or low interest loan program that encouraged the community to participate. The initial outside funding for capital investment apparently was emphasized more than the long turn net disposal fees needed to support annual costs.

We suggest that the use of Federal and state legislation to the further objectives of resource recovery take into account the discounted long term effects of participation. An analogy might be the wealthy father who helps buy his 17 year old son a Corvette only to later learn that the son cannot pay the $500 per year insurance premium.

A specific reason for the high cost at Werdenberg is that costs must be divided by only 120 ton per day. This is the only plant surveyed that we can clearly say suffers from diseconomies of scale. A single 120 tonne, (132 ton) per day line with standby energy backup is too small. This is especially small considering the diverse energy uses (hot water for district heating, steam for the chemical plant and electricity for the network).

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[*] (1) Engdahl, R. E. Nashville --
(2) Lowe, R., McEwen, L. Nashville --

Despite the above economic pattern, these two researchers love the plant, its community and complexity of system engineering. In a bold manner we state, "There is no place in the world that you can see more intriguing energy applications for a 132 ton per day refuse input than Werdenberg-Liechtenstein".

Wuppertal with a $35.66 per ton net disposal cost is adversely affected today because of concern for the future capacity. Of its four furnaces one is always down because of the impact of sparce refuse supply to the system. A second unit is usually down for preventive maintenance or repairs. Thus the total costs for this sophisticated electrical generating plant with four lines must be supported with the activity in only two lines.

Planners in other situations would have built 3 units and left an open bay for a later 4th. Perhaps refuse imput from a neighboring community will increase operations and spread fixed expenses over more tonnage.

The Hamburg: Stellinger-Moor system at $22.55 per ton has unusually high labor costs. The cost $14.95 per ton for operations and maintenance labor and materials was the highest in the survey. A second observation was that the revenue of $5.92 per ton from sale of energy is a bit low.

Zurich: Hagenholz achieved very reasonable and aceptable results at $12.66 per ton for several reasons. Frankly the professional administrative spirit of the Director is to be highly credited. A spirit of pride and efficiency pervades all activities. Job positions must continually be justified. Total operations and maintenance labor and materials was only $4.06 per ton, the lowest in the survey. Comparatively, the interest and depreciation is high at $15.31 per ton. This is consistent with management's emphasis favoring purchase of what he considers to be the best equipment to reduce labor and material needed for operations and maintenance. Thirty-three (33) separate design and operation decisions were identified specifically to reduce corrosion. As a result, the superheater tubes have suffered only 0.3 mm (0.012 in) metal wastage in five or six years. Other tubes have lost only 0.1 mm (0.004 in) in the same 30,000 hours. This is remarkable and has proven that high temperature steam, 788 F, can be produced at a price with virtually no corrosion if proper design and operation decisions are made and carried through.

Battelle staff have attempted to analyze the wide variation in results, $6.27 up to $48.25 per ton, by manufacturer or prime vendor. While averages can be derived and arrayed, we feel that the local situations far outweigh vendor importance. Besides that, our sampling of only two or three plants per vendor is not enough to develop significant conclusions.

However, it should be pointed out that each of the four refractory wall systems performed better than the survey average. Yet the two surveyed manufactures have not yet mounted an effective North American marketing effort in recent times. At this writing, Fall 1978, Brunn and Sorenson has no North American representative. Volund has appointed a new representative in Washington, D.C. It is our opinion that American resource recovery competitions would benefit by marketing efforts also from European and North American manufactures of refractory wall incinerator-waste heat recovery boiler vendors.

Specific Comments About Expenses and Revenues

Werdenberg-Liechtenstein

The detailed schedule of 1976 expenses and revenues is presented in Table L-13.

These are important financial numbers because they highlight several facts. First, the plant was built in part due to the Swiss Federal financing program that provided 70 percent of the capital investment. Such a gracious offering of funds for resource recovery spurred energy Swiss communities to build systems that otherwise might not have been built. Now the law continues but the funds have long been expended. This apparently is one reason that construction of completely new Swiss systems to have dramatically slowed.

Second, researchers were told that the manufacturer had made it clear to community officials that, "This plant is going to be expensive. Citzens hould expect to pay substantially more for resource recovery than for open dumping."

Third, the economics of scale of such a small 120 tonne (132 ton) per day plant are poor. Yet the plant design is very compact. It is an efficient way to design and operate such a small sized plant.

Fourth, the amortization or depreciation of the capital investment alone is $24.04 per ton. Adding interest bring the total to $35.61 per ton for principal and interest payments.

Fifth, because the plant only operated during the 5-day week, heating oil and gas must be used on weekends in the amount of $3.35 per ton of incoming refuse.

Unfortunately, all expenses together result in a $54.64 per ton cost --- the highest of visited plants. The sale of energy is only $5.80 per ton which is slightly over 10 percent of total costs. Here as at many other co-generation facilities, the best economic decision is to produce district heating energy as the primary focus. Only when this demand falls (as in the summer) does the focus switch to electricity production.

Waste oil processing produces 27,209 S.Fr. ($11,101) revenue per year. Selling compost is almost an activity of the past because demand is so low. (This is not a wine-growing region as at Biel, Switzerland). Sale of scrap iron brings in only $0.14 per refuse input ton.

The end result is a net disposal fee of $48.25 per ton, one of the highest fees in Europe.

A more detailed picture can be seen in the 1977 estimate of revenues as shown in Table L-14. The tipping fee assessed directly and subsidized has been set lower than in 1976 due to anticipated lower costs. This table of revenues showing the 12 sources of annual revenues dramatically portrays the revenue raising potential for a single 120 tonne per day refuse fired steam generator with an oil-fired standby boiler. Since the RFSG plant only operates 5 days per week, the standby boiler is regularly used. The reader is again reminded that these revenues are for the total four-building complex. Dump fees for animal waste and from sale of compost are the only revenues not tied to the RFSG. Note that revenues are expected to rise from $54.64 (in 1976) to $61.79 per ton in 1977.

TABLE L-13. OPERATIONS RESULTS AT WERDENBERG-LIECHTENSTEIN FOR 1976

	S.Fr/Year	S.Fr./Tonne	1976 U.S.$ / Ton	Percent (%)
Operating expenses (labor)	602,224	23.15	8.59	15.71
Building maintenance	5,178	0.20	0.07	0.13
Equipment maintenance	5,633	0.22	0.08	0.15
Compost facilities	1,482	0.06	0.02	0.04
Refuse burning plant	96,582	3.71	1.38	2.52
Animal incineration	131	-	-	-
District heating lines	96	-	-	-
Tools and furniture	219	0.01	-	0.01
Truck maintenance	6,009	0.23	0.09	0.15
Electricity	58,711	2.26	0.84	1.53
Miscellaneous supplies	8,386	0.32	0.12	0.22
Diesel oil	4,427	0.17	0.06	0.12
Heating oil and gas	235,171	9.04	3.35	6.13
Cleaning materials	1,461	0.06	0.02	0.04
Lubricants	2,310	0.09	0.03	0.06
Chemicals	3,734	0.14	0.05	0.10
Scrap iron disposal	45,361	1.74	0.65	1.18
Gretschans landfill	2,275	0.09	0.03	0.06
Buchserbert landfill	81,355	3.13	1.16	2.12
Miscellaneous expense	5,219	0.20	0.07	0.14
Special expense: Canal connection	80,104	3.08	1.14	2.09
Insurance	75,795	2.90	1.08	1.98
Administration	13,330	0.51	0.19	0.35
Interest paid on loans	811,626	31.19	11.57	21.18
Depreciation	1,685,998	64.80	24.04	43.98
Budget planning	579	0.02	0.01	0.01
TOTAL EXPENSES	3,832,817	147.31	54.64	100.00
Traxarbeiten (?)	244	0.01	-	0.01
Abfur Fl + Sgs. (?)	431	0.02	0.01	0.01
Sale of compost	468	0.02	0.01	0.01
Sale of scrap iron	9,555	0.37	0.14	0.25
Used oil processing	27,209	1.04	0.38	0.71
Sale of heat (steam and hot water)	346,401	13.31	4.94	9.04
Sale of electricity	60,291	2.32	0.86	1.57
General disposal fees	3,384,849	130.09	48.25	88.31
Balance (?)	3,363	0.13	0.05	0.09
TOTAL REVENUES	3,832,817	147.31	54.64	100.00

Example: $\frac{602{,}224\ \text{S.Fr.}}{1\ \text{year}} \left(\frac{1\ \text{U.S. \$}}{2.451\ \text{S.Fr.}}\right) \left(\frac{1\ \text{year}}{26{,}018\ \text{Tonne}}\right) \left(\frac{1\ \text{Tonne}}{1.1\ \text{Ton}}\right) = \$8.59/\text{Ton}$

i.e., Multiply all S.Fr./Year by .0000142557 to obtain 1976 U.S. $/Ton

TABLE L-14. REVENUE ESTIMATE FOR 1977 AT WERDENBERG

	Annual Volume	Unit Charge Old (S.Fr.)	Unit Charge New (S.Fr.)	New Revenue (S.Fr.)	1977 U.S. $ Per Ton
Dump Fee Household & Bulky Waste	20,000 Tonnes	90	80	1,600,000	$ 31.46
Dump Fee, Industrial Waste	3,000 Tonnes	120	100	300,000	5.90
Dump Fee, Animal Waste	300 Tonnes	150	150	45,000	0.89
Dump Fee, Scrap Iron	150 Tonnes	200	200	30,000	0.59
Subsidized Head Tax	76,685 People	12	10	766,850	15.08
Sale of Compost (1976 data)				468	0.01
Sale of Scrap Iron				5,000	0.10
Scale of Waste Oil				25,000	0.49
Sale of Warm Water (District Heating) Sale of Steam (Chemical Industry Process Steam)				32,000	6.29
Sale of Electricity (1/2) Internal Credit for Electricity (1/2)				50,000	0.98
TOTAL REVENUES				3,142,318	61.79

Werdenberg-Liechtenstein Plant, Courtesy of the Society for Refuse Disposal, 1976 Annual Report, Widmer + Ernst (Alberti-Fonsar)

Example: $\frac{1{,}600{,}000 \text{ S.Fr.}}{1 \text{ year}} \left(\frac{1 \text{ U.S. \$}}{2.010 \text{ S.Fr.}}\right) \left(\frac{1 \text{ year}}{23{,}450}\right) \left(\frac{1 \text{ Tonne}}{1.1 \text{ Ton}}\right) = \$31.463$

i.e., Multiply all S.Fr./year numbers by .0000196645 to obtain 1976 U.S. $/Ton

Baden-Brugg

Table L-15 shows that total revenue collected amounted to $25.25 per ton in 1976. This was $4.34 per ton more than expenses. This thus results in a truer expense figure of $20.91 per ton.

Note that $18.63 per ton was collected from municipal contributions. Perhaps this should be reduced by the above amount to $14.29 per ton as a net disposal fee to be supported by the taxpayers. This appears most impressive when one considers that only 114 tonnes (125 tons) per day are processed over the 365 day year.

Some of these expenses were to cover operations at the wastewater treatment and clarification plant. There were other included expenses to cover waste oil reception, decantation and burning.

With the exception of a small amount of steam sent to the adjoining hazardous waste treatment plant and the wastewater treatment plant, the only real energy market is electricity sale to the regional AEW utility. This produced a $6.17 per tonne ($5.61 per ton) revenue.

Assuming that 140,000 people live in the service area, the net cost of municipal solid waste disposal (not including collection) is roughly $4.68 per person per year.

Duesseldorf

The expenses for 1975 shown in Table 1-16 show that the combination of operations and maintenance about equals the amortization expense; each being about 41 percent of the total $20.40 per ton.

A separate set of 1975 figures show the distribution of maintenance into these three categories:

Maintenance by plant staff	23.5 percent
Maintenance by outside contracts	51.1
Maintenance materials	25.4
	100.0 percent

Management at Duesseldorf believes that maintenance costs can be minimized by supporting a minimal permanent maintenance staff with heavy use of outside contractors (51.1 percent). A key contractor is another City Department, the power plant.

Revenue to the plant comes from the sale of steam, residue, and scrap iron.

The city power system considers the value of the steam received to be 1.017 times the cost of the coal that would be needed to genereate that steam. In 1977, that amounted to 15 D.M./tonne ($6.30/ton) of steam ($2.86/1,000 lb).

Table L-17 shows the plant income of 1975. This table is most important demonstration of resource recovery revenues ratios. Without hesitation, it can be said of Duuesseldorf that it has one of the most advanced steel scrap and ash processing systems in the world. Yet steel operations bring in only 10.8 percent of the total resource recovery revenue (excluding tipping fees) while ash generates only 0.5 percent.

TABLE L-15. OPERATING RESULTS FOR 1976 AT BADEN-BRUGG

Expenses	S.Fr./Year	S.Fr./Tonne	U.S. $/Ton	Percent(%)
Attendance Fees	1,840	0.04	$ 0.02	0.06
Directors salaries	12,008	0.29	0.11	0.42
Staff salaries (regular)	818,263	19.63	7.28	28.83
Staff salaries (auxiliary)	6,900	0.17	0.06	0.24
Social insurance	108,476	2.60	0.97	3.83
Tool and Equipment Purchases	3,843	0.09	0.03	0.14
Office Supplies	7,477	0.18	0.07	0.26
Cleaning materials	771	0.02	0.01	0.03
Operating materials	16,260	0.39	0.14	0.57
Heating materials	10,797	0.26	0.10	0.38
Electricity and Water (RFSG)	42,084	1.01	0.37	1.48
Electricity (clarification plant)	62,144	1.49	0.55	2.19
Maintenance of machines & devices	89,285	2.14	0.79	3.16
Maintenance of tools & furniture	5,164	0.12	0.05	0.19
Maintenance of buildings	6,044	0.14	0.05	0.21
Maintenance of vehicles	1,497	0.04	0.01	0.05
Transport ash removal	93,729	2.25	0.83	3.30
Landfill charge for ash	67,473	1.62	0.60	2.38
Vehicle expenses	3,477	0.08	0.03	0.12
Other material expenses	594	0.01	0.01	0.02
Telephone	1,799	0.04	0.02	0.06
Liability & property insurance	48,640	1.17	0.43	1.71
Bank service charge	2	-	-	-
Interest on debt	382,645	9.18	3.40	13.48
Amortization	559,725	13.43	4.98	19.72
"Contribution to reserves"	487,363	11.69	4.34	17.17
TOTAL EXPENSES	2,838,300	68.08	$ 25.25	100.00
Revenues				
Withdrawals from revenues	0	0	0	0
Interest on reserves	2,443	0.06	$ 0.02	0.09
Rentals and leases*	11,841	0.28	0.11	0.42
Unemployment compensation	2,377	0.06	0.02	0.08
Sale of electricity	693,121	16.62	6.17	24.42
Various receipts	34,094	0.32	0.30	1.20
Municipal contributions	2,094,424	50.24	18.63	73.79
TOTAL REVENUES	2,838,300	68.08	$ 25.25	100.00

*Lease of former Compost building to Fairtec, the hazardous waste processing plant.

Example: $\frac{1{,}840 \text{ S.Fr.}}{1 \text{ Year}} \left(\frac{1 \text{ U.S. } \$}{2.451 \text{ S.Fr.}}\right)\left(\frac{1 \text{ Year}}{41{,}693 \text{ Tonnes}}\right)\left(\frac{1 \text{ Tonne}}{1.1 \text{ Ton}}\right) = \$0.04$ per Tonne

i.e., Multiply all S.Fr. numbers by .0000088961 to obtain 1976 U.S. $/Ton.

TABLE L-16. COSTS OF THE WASTE BURNING FACILITY AT DUESSELDORF, 1975

	D.M.	U.S. 1975 $ per Ton	Percent (%)
Operating expense including 80 percent overhead on salaries and wages and 10 percent overhead on other costs	2,707,858.03	$ 3.16	16.19
Maintenance expense with overhead	4,216,217.39	4.92	25.19
Miscellaneous expense with overhead	763,636.37	0.89	4.56
Operational fee surcharge of 5 percent without electricity, water, or fuel	256,511.93	0.30	1.53
Management fee of Sanitation Department	321,157.70	0.37	1.92
Insurance	130,190.00	0.15	0.78
Electricity, water	1,267,719.68	1.48	7.57
Fuel	2,152.85	-	0.01
Ash and scrap hauling	126,695.16	0.15	0.76
Principal payback plus interest	6,944,611.78	8.10	41.49
TOTAL	16,736,650.89	$19.52	100.00

Example: $$\frac{2{,}707{,}858.03\text{ D.M.}}{1\text{ Year}}\left(\frac{1\text{ U.S. \$}}{2.622\text{ D.M.}}\right)\left(\frac{1\text{ Year}}{297{,}359\text{ Tonnes}}\right)\left(\frac{1\text{ Tonne}}{1.1\text{ Ton}}\right) = \$\underline{3.16/\text{ton}}$$

i.e., Multiply all D.M./year numbers by .0000011659 to obtain 1975 U.S. $/Ton

TABLE L-17. DUESSELDORF REVENUES FROM SALE OF STEAM, BALED SCRAP STEEL AND PROCESSED ASH IN 1975

	Steam	Baled Scrap Steel	Ash
Gross Weight Produced (Tonnes)	590,814	9,180	105,092
Net Weight Sold (Tonnes)	560,002	9,180	48,000
Net Weight Sold (Tons)	616,002	10,098	52,800
Revenue per Tonne of Product (D.M./Tonne)	14.51	107.51	1.01
Revenue per Ton of Product ($ U.S./Ton)	5.03	37.28	0.35
Total Revenue (D.M.)	8,125,629	986,987	48,596
Total Revenue ($ U.S.)	3,099,019	376,425	18,534
Percent of Total Revenue (%)	88.7	10.8	0.5
Revenue per Refuse Input Tonne (D.M./Tonne)	27.32	3.32	0.16
Revenue per Refuse Input Ton ($/Ton)	9.47	1.15	0.06

Where: 1.0 Tonnes equals 1.1 Tons

2.622 D.M. equals $1.00 in 1975

The total revenue by calculation $3,493,978

Refuse input tonnes 297,359

Refuse input tons 327,095

Here, as elsewhere, the overwhelming income comes from energy sale---88.7 percent.

However, by such through processing, the new weight to be disposed on land is very small percentage of the refuse input tonnage. While not available at this time, it would be interesting to comapre the marginal revenue with marginal expenses associated with both steel scrap and processed ash.

Wuppertal

The plant was still under construction in the scrubber area in 1977. It was therefore operating on a reduced schedule of only half of full capacity. Long term costs were thus not yet well established. The estimated net disposal cost for 1976 was 79.80 D.M./tonne ($33.77/ton) after credits are taken for sale of the residue and electricity. This rather high figure is expected to decline as moore refuse is burned and capacity is approached. However, the cost of maintenance of the Government-mandated scrubbers could adversely effect total operating cost in later years.

Local officials hope that with the plant operating at nominal capacity in 1978, the cost will decrease to 65 or 70 D.M./tonne ($31.92 or 34.38/ton).

Of the above total costs, they estimate a "fixed" operating cost regardless of throughput of 20,000,000 D.M. per year. This fixed portion would amount to 50 D.M./tonne ($24.56/ton) in 1978 if the expected three units ran at capacity 365 days per year. Thus fixed costs are about 3/4 of total cost.

In 1976 the revenue from the sale of electricity was 3,500,000 D.M. $1,481,000. Tipping fees totalled 16,500,000 D.M. $6,983,000. The 1976 throughput was 178,000 tonnes (195,800 tons). These totals translate to an income of 112.36 D.M./tonne (43.23/ton). However, the actual tonnage in 1976 was much less than capacity.

Each household served pays an annual fee of 230 D.M. for rental of a 110 liter (29 gallon) container that is emptied once per week. Estimated expected public collection in Wuppertal was 110,000 tonnes in 1976 but actual public collection was only 94,000. Remschied collected 16,000. Private haulers brought 68,000 for a grand total of only 178,000 tonnes (195,800 tons).

Ash residue income is 1.5/tonne ($0.58/ton) of residue.

Krefeld

The only cash income to the Krefeld plant comes from the sale of the energy in hot water to a local railroad car plant at the rate of D.M. 0-35/Gcal (D.M. 7-8/GJ) $3.6 - $4.2/MBtu.

Paris:Issy

Paris:Issy had the best 1976 operating results (See Table L-18) of any visited plant. A per ton total expense figure of $12.78 is an

TABLE L-18. OPERATING RESULTS FOR PARIS:ISSY DURING 1976

	Total Expenses		U.S. $	Percent
	Thousands	of F.Fr.	Per Ton	(%)
Operations Expenses	8,441	14.34	2.62	20.53
Maintenance - General	7,015	11.92	2.18	17.06
Maintenance Inspections	4,508	7.66	1.40	10.96
Maintenance - Specific	1,427	2.43	0.44	3.47
Testing and Verification	1,762	2.99	0.54	4.28
Revisions After Testing	90	0.15	0.03	0.22
	452	0.77	0.14	1.10
	528	0.90	0.16	1.28
Training and Safety	311	0.53	0.10	0.76
Purchased Services	1,257	2.14	0.39	3.05
General Expenses	1,269	2.16	0.39	3.09
Total Operating and Maintenance Expenses	27,060	45.99	8.40	65.80
Transporting Waste	921	1.57	0.29	2.24
Sales Expense	25	0.04	0.01	0.06
Amortization	7,813	13.28	2.43	19.00
Interest Charges	491	0.83	0.15	1.19
Share of Central Services	4,815	8.18	1.50	11.71
Total Other Expenses	14,065	23.90	4.38	34.20
TOTAL EXPENSES	41,125	69.89	12.78	100.00
Sales of Electricity and Steam	(20,091)	(34.14)	(6.25)	(48.85)
Sales of Road Ash and Scrap Metal	(828)	(1.41)	(0.26)	(2.01)
TOTAL REVENUE	(20,919)	(35.55)	(6.51)	(50.86)
NET RESULT (Effective Tipping Fee)	20,200	34.33	6.27	49.12

Example: $\frac{8{,}441{,}000 \text{ F.Fr.}}{1 \text{ Year}} \left(\frac{1 \text{ U.S. \$}}{4.970 \text{ F.Fr.}}\right) \left(\frac{1 \text{ Year}}{588{,}904 \text{ Tonnes}}\right) \left(\frac{1 \text{ Tonne}}{1.1 \text{ Ton}}\right) = \$\ 2.62/\text{Ton}$

i.e., Multiply all F.Fr. numbers by .0000003108 to obtain 1976 $/Ton.

accomplishment for which the staff of TIRU can be most proud. Selling electricity and district heating steam at $6.25/refuse input ton have enabled TIRU to recover about half of their costs. Sales of road ash and scrap metal bring in only $0.26 per refuse input ton but do greatly reduce landfill costs for residue disposal.

There are several reasons for this excellent financial performance. Most of the steam is sold for use in district heating by a separate organization described later, CPCU. The refuse burning organization TIRU has none of the expenses of network distribution. Electricity, which commands less revenue per refuse imput ton, is produced in the summer so that little annual steam production is wasted.

Practically speaking, however, it may be more difficult to institutionally develop a district heating market in many cities. Pure electrical production may be the only alternative. The reason for lower revenues from electricity sale is that the RFSG plant must compete with conventional fossil fueled or nuclear power plants 100 times larger. In most countries, there is a national grid of economically produced power that forces a low sale price for electricity.

Figures L-6 and L-7 show the unit sale price pattern for electricity and steam. The upper line shows the inflated current dollars, while the bottom line shows the same results but in constant 1962 dollars.

Effects of the 1973 Arab oil embargo are clearly shown. The constant unit sale price for both electricity and district heating steam had gradually been falling from 1962 through 1973, the unit prices (especially the current price) began a steep rise; doubling by 1976. Thus, assuming that costs continued to be contained, there was a "windfall" gain in revenues.

A second reason for increases in revenues is that a CPCU labor settlement caused a sudden jump in steam sale price as shown in the dashed lines.

Another credit for the excellent financial results is due to the stable, mature and intelligent staff as assembled by Mssr. Defeche at TIRU. The spirit of research and development cooperation between his staff and the staff of Martin has certainly contributed to improved methods.

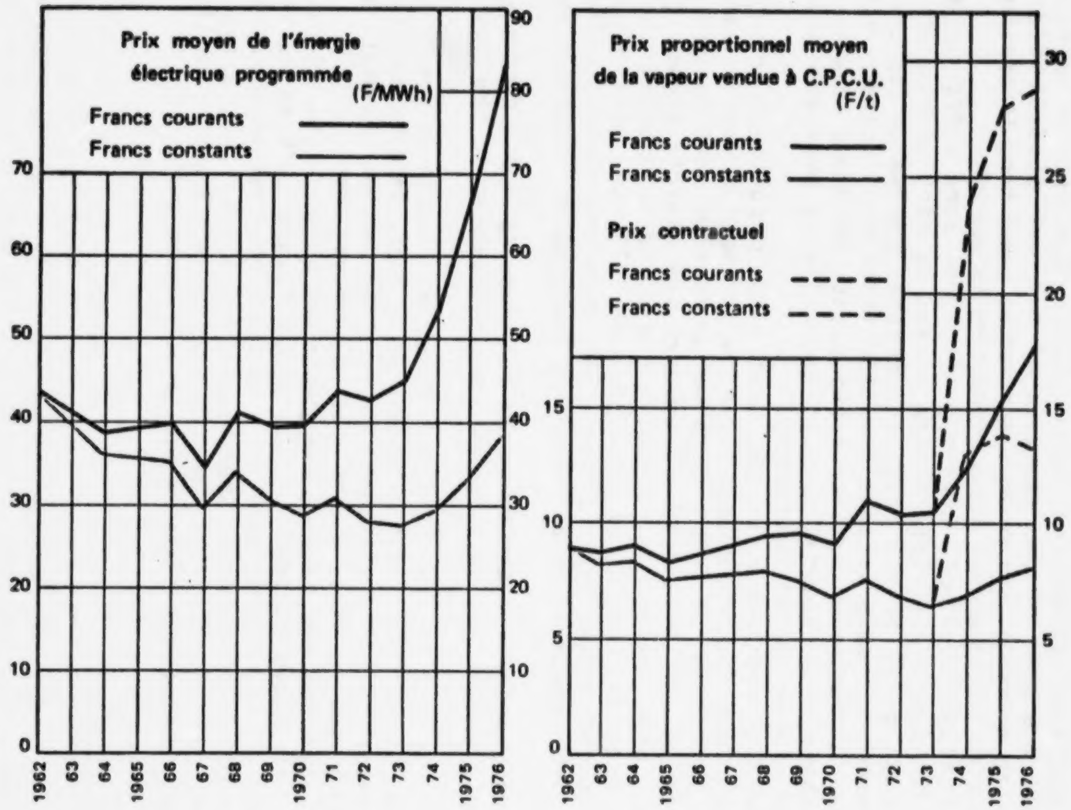
Total expenses and revenue components are shown in the following figures. Figure L-8a shows current dollars while Figure L-8b shows 1976 constant dollars. These figures parallel a Battelle observation about RFSG revenues in both Europe and in North America. Generally speaking, a system that has a heavy load of district heating (and possibly summer cooling) will have greater revenue than a system making only electricity.

Hamburg: Stellinger-Moor

The 1976 operating results for both MVAI (Borsigstrasse) and MVA II (Stellinger-Moor) are shown in Table L-19. Separate figures for Stellinger-Moor were unavailable.

The net disposal or tipping fee is $22.55 per ton. The other revenue producing activity is electricity sale in the amount of $5.92 per ton. Together they equal the total cost of $28.47 per ton.

Part of the reason for the relatively high costs is the observation by these researchers of more men working at a more leisurely



FIGURES L-6 AND L-7. UNIT PRICES FOR ELECTRICITY AND STEAM IN PARIS (TIRU)

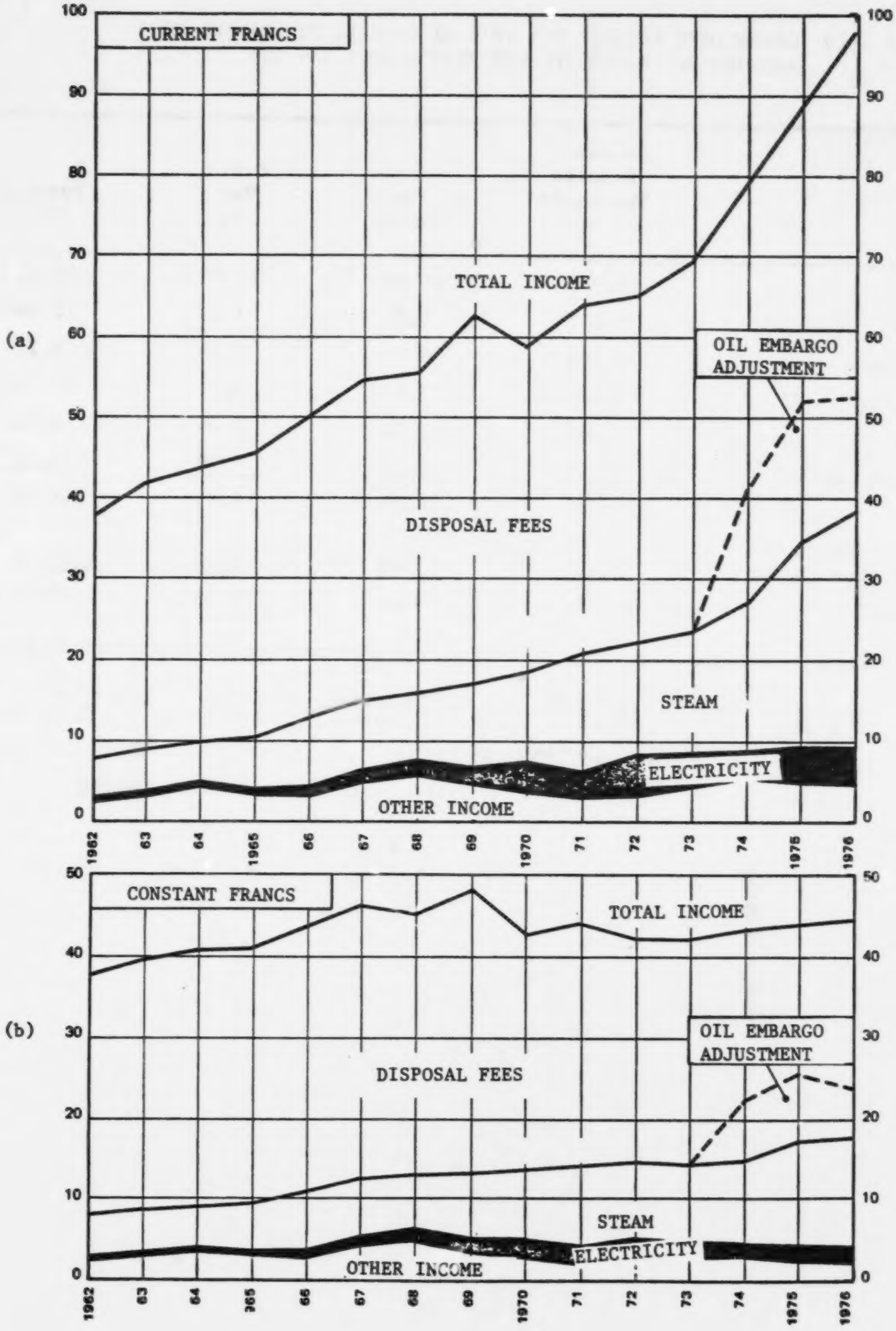


FIGURE L-8a and b. REVENUE AND EXPENSE COMPONENTS FOR THE FOUR TIRU PLANTS

TABLE L-19. OPERATIONS RESULTS FOR 1976 AT HAMBURG:STELLINGER-MOOR AND HAMBURG:BORSIGSTRASSE PLANTS (MVA I + II)

	Annual Results Thousands of D.M.	D.M. Per Tonne	U.S. $ Per Ton	Percent (%)
Labor	10,975	26.09	10.03	35.25
Material	3,817	9.07	3.49	12.26
External Fee	2,729	6.49	2.50	8.77
Amortization	3,844	9.14	3.51	12.35
Overheads	1,561	3.71	1.43	5.01
Interest on Capital	8,206	19.50	7.50	26.36
	31,132	74.00	28.47	100.00
Electricity Sales and Internal Use Credit	6,478	15.40	5.92	20.81
NET Disposal or Tipping Fee	24,654	58.60	22.55	79.19

Example: $$\frac{10{,}975{,}000\text{ D.M.}}{1\text{ Year}}\left(\frac{1\text{ U.S. \$}}{2.363}\right)\left(\frac{1\text{ Year}}{420{,}680\text{ Tonnes}}\right)\left(\frac{1\text{ Tonne}}{1.1\text{ Ton}}\right) = \$10.03/\text{Ton}$$

i.e., Multiply all D.M. numbers by .0000009145

Source: Annual Report for 1976, page 17 - Jahresbericht der Stadtreinigung pace that had been observed at many other plants. The local municipal labor union seems to wield substantial influence on plant activities. Perhaps this parallels the obviously needed influence that was necessary to implement the incentive collection system.

Zurich: Hagenholz

A separation of annual costs to operate the Von Roll Units No. 1 and No. 2 from operation costs for the Martin Unit No. 3 is impossible. Annual 1976 costs, totaling SF 14,414,893, include costs of operations, maintenance, interest, and other costs, and are portrayed in Table L-20.

The total costs are reasonable at $23.91 per ton. The single most expensive item is amortization at $11.38 per ton or 47.6 percent of the total. This is consistent with top management's emphasis on obtaining the best equipment available (regardless of initial capital investment costs) that will produce a reasonably low net disposal fee for the taxpayer.

Unit No. 3, especially, has had very low maintenance requirements. In fact all three units needed only $1.55 per ton for maintenance expenditures (excluding labor wages).

Another important number is $3.14 per ton for wages. This is only 13.14 percent of the total costs. Apparently the managerial and plant bonus of 20,354 S.Fr. ($8,304) had, in part, contributed to controlling labor costs. Frankly, the powerful and effective leadership provided by the Director, Max Baltensperger is, in our opinion, to be credited. As an example, management will appear at the plant unannounced at 2:00 a.m. Those employees not busy on necessary work will cause initiation of a work analysis program to determine if the position is really needed. As a result, this plant that processes up to 700 tonnes (770 tons) per day has only 39 employees for the seven/day week.

Figure L-9 shows the history of collection and disposal costs in Zurich since 1928. Again, this costs for all government solid waste operations have been well controlled since 1970.

Annual 1976 revenues, also totaling SF 14,414,893, include tipping fees; sale of steam, hot water, electricity and unburned ferrous; a large insurance settlement for a turbine; rent of a tire shredder; credit for repairs to other City of Zurich vehicles and other incomes. See Table L-21.

Dividing the tipping fee, charged to non-Abfuhrwesen trucks, of 2,210,966 S.Fr. by the annual tonnage of 94,000 tonnes, yields a S.Fr. 23.46/ tonne tipping fee. However, the public tipping fee charged, and the subsidy later paid total of 5,417,988 S.Fr. divided by 121,559 tonnes, yields a public Abfuhrwesen collection tipping fee per ton of SF 44.57/tonne.

The question was asked, "Why would you charge outsiders only 23.46 S.Fr./refuse tonne and charge your own taxpayers 44.57 S.Fr./refuse tonne--almost twice as much?" The answer was three-fold and is paraphased as follows:

> Answer 1. "Hagenholz is an energy plant and we need as much fuel as possible. Even though the tipping fee is half, we are still being paid to accept fuel."

TABLE L-20. ANNUAL 1976 OPERATING, MAINTENANCE, INTEREST, AND OTHER COSTS FOR ZURICH:HAGENHOLZ UNITS #1, #2, AND #3

	Component	Totals	S.Fr. Per Tonne	U.S. 1976 $ Per Ton	Percent (%)
Interest	2,365,967	2,365,967	10.58	3.93	16.42
Plant Amortization	6,731,680				
Office Equipment Amortization	19,186				
Spare Parts Amortization	110,205				
Total Amortization		6,861,071	30.69	11.38	47.60
Office Wages	148,323				
Managerial Wages	162,278				
Part-time Wages	4,146				
Plant Wages	1,576,561				
Total Wages		1,891,307	8.46	3.14	13.14
Managerial Bonus	2,737				
Plant Bonus	17,617				
Total Bonus		20,354	0.09	0.03	0.14
Overalls and Clothing		8,354	0.04	0.01	0.06
Cafeteria Subsidy		16,540	0.07	0.03	0.10
Cost of Living Pension Adj.	79,258				
Planned Pension	124,798				
Makeup Pension	99,198				
Social Security Pension	92,405				
Total Pension		395,659	1.77	0.66	2.75
Accident and Sickness Insurance		35,748	0.16	0.06	0.25
Office Supplies		422	-	-	-
Ash Research and Treatment (net cost)		1,374,782	6.15	2.28	9.54
Other Department Services		14,825	0.07	0.03	0.10
Studies		994	-	-	-
Building	60,271				
Chute-to-Stack	680,809				
Ash Truck (1)	1,077				
Landscape on Old Landfill	60,697				
Workman Clean-Up Room	4,989				
Plant Controls (est.)	42,629				
Boiler Cleaning (est.)	80,000				
Cafeteria Repairs and Cleaning	5,008				
Total Repairs (no wages)		935,483	4.18	1.55	6.49
Janitorial Service (est.)	3,000				
Heating (est.)	2,973				
Office and Repair Shops		5,973	0.03	0.01	0.04
Cleaning Supplies		11,861	0.05	0.02	0.08
Fuel Oil	19,217				
Electricity Purchase	105,949				
Water	201,821				
Electricity for Office	184				
Total Utilities		327,173	1.46	0.54	2.27
Truck TBA and Diesel Oil		790	-	-	-
Oil and Lubricants for Plant		11,223	0.05	0.02	0.08
Electrical Replacements (lamps)		10,440	0.05	0.02	0.07
Chemicals for Water Treatment		15,332	0.07	0.03	0.11
Office Costs Burden		30,773	0.14	0.05	0.21
Property and Liability Insurance		75,151	0.34	0.13	0.52
Tax Overpayment		(3,465)	(0.01)	(0.01)	(0.02)
Hospitality		2,849	0.01	-	0.02
Damages not covered by Insurance		4,098	0.02	0.01	0.03
GRAND TOTAL COSTS		14,414,893	64.47	$ 23.91	100.00

Example: $\frac{2,365,967 \text{ S.Fr.}}{1 \text{ Year}} \quad \frac{1 \text{ U.S. \$}}{2.451 \text{ S.Fr.}} \quad \frac{1 \text{ Year}}{223,595 \text{ Tonnes}} \quad \frac{1 \text{ Tonne}}{1.1 \text{ Ton}} = \$\ 3.93/\text{Ton}$

i.e., Multiply all S.Fr./year numbers by .0000016588 to obtain $/Ton

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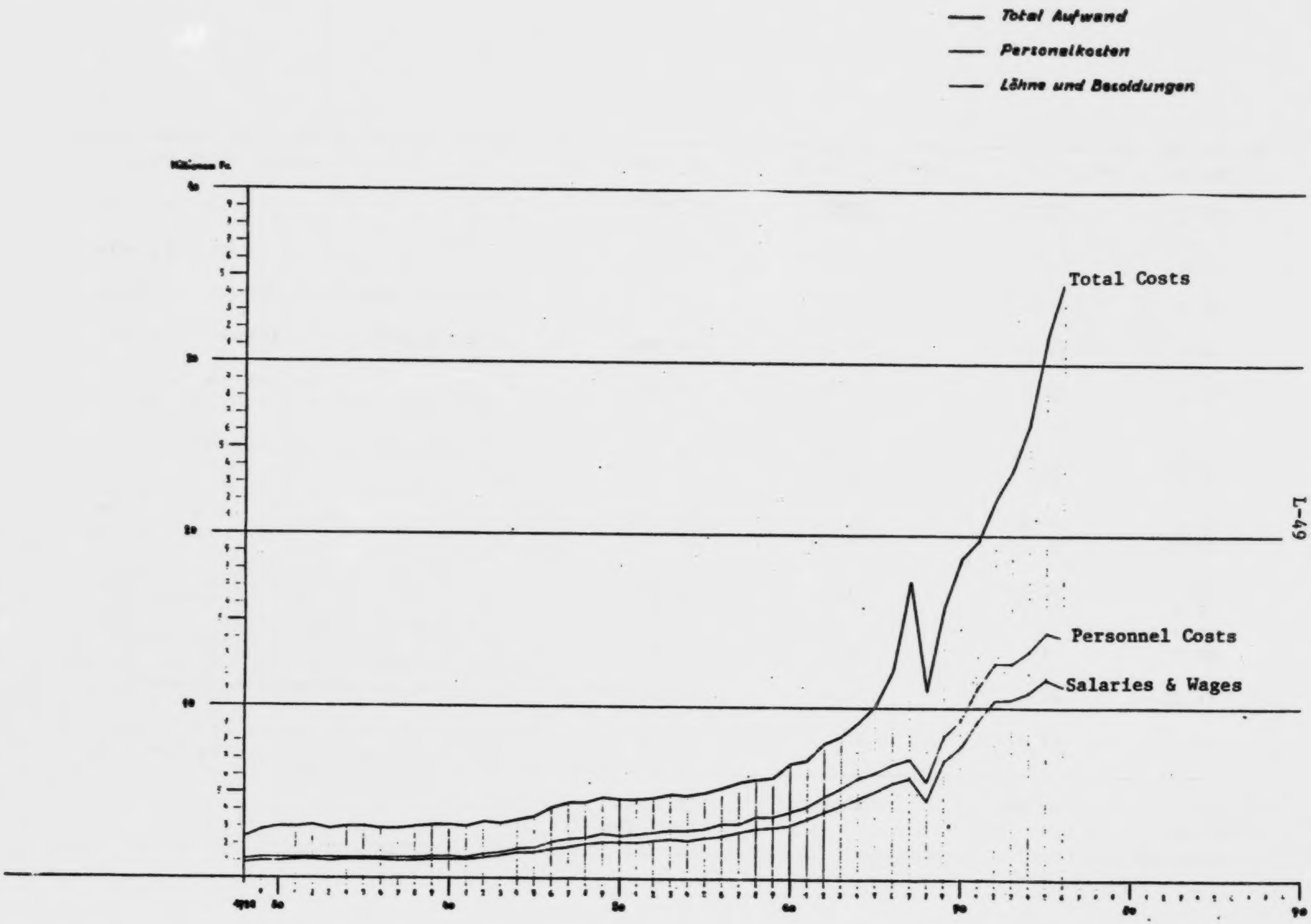


FIGURE L-9. COSTS OF ZURICH CLEANSING DEPARTMENT SINCE 1928

TABLE L-21. ANNUAL 1976 REVENUES FOR ZURICH:HAGENHOLZ UNITS #1, #2, AND #3

	Annual Total S.Fr.	S.Fr. per Tonne	U.S. 1976 $ per Ton	Percent (%)
Rent paid by Widmer and Ernst for use of City's Tire Shredder	64,000	0.29	0.11	0.41
Citizen and Business Tipping Fee	4,032,685	18.04	6.69	27.95
Comm. and Ind. and Apt. Container Fee City trucks pick-up	2,210,966	9.89	3.67	15.35
Portion of General Tax to dispose of household refuse	1,385,303	6.19	2.30	9.62
TOTAL TIPPING FEE	7,628,956	34.12	12.66	52.92
District Heating	5,057,987	22.62	8.39	35.05
Electricity	1,036,155	4.63	1.72	7.18
Ferrous Scrap Sale (containers) never burned	14,813	0.07	0.02	0.08
TOTAL ENERGY AND MATERIALS SALES	6,108,956	27.32	10.13	42.31
Credit for repairs to other City Dept. trucks, motors, etc.	45,951	0.20	0.08	0.33
Insurance payment for turbine break	553,941	2.48	0.92	3.86
Refund on personnel accident insurance	4,999	0.02	0.01	0.04
Miscellaneous	27,129	0.12	0.04	0.17
Adjustment**	(9,670)	(0.04)	(0.02)	(0.04)
GRAND TOTAL REVENUES	SF 14,424,262	SF 64.51/Tonne	23.91/Ton	100.00%

*

**

Answer 2. "The non-Abfuhrwesen waste typically has a desirable higher heating value" (bad for Units No. 1 and No. 2, good for Unit No. 3).

Answer 3. With more waste, our fixed costs are spread over more refuse tonnes and total unit costs will be less. The 44.57 S.Fr./tonne figure would be higher if others were not to bring waste to Hagenholz.

The scrap iron collected in plant containers before burning is sold for about $2.00 per ton, which is about one cubic meter.

Neither the revenue nor expense tables has an entry for sale of ash residue--either ferrous or road building material. This is because the ash processing is operated separately. The result is a "net cost" and that is recorded in the annual cost table.

Both the 1976 annual costs and revenues are summarized below:

Annual Revenue	SF 14,424,262
Annual Cost	14,414,893
Net Profit	SF 9,369

A net profit figure is somewhat fictictious because of the subsidy calculation designed to make net profit come out to near zero. This deductive subsidy figure appears in the revenue table as "portion of general tax to dispose of household refuse".

As is typical of RFSG plants that manufacture both electricity and district heating; most of the energy revenues come from district heating (35 percent) less from electricity (7 percent) and very little from scrap metal pulled from the refuse stream before burning.

Comment: As Battelle staff has viewed systems in many countries, usually energy economics strongly favors sale of energy for district heating (and perhaps cooling for the summer load). This is in contrast to the competitive electricity prices normally held down by economical production at very large (100 times the mw size) hydro, fossil, or nuclear power plants.

The Hague

Table L-22 presents summary costs and revenues for 1976 at The Hague. The major component of expense was the principal and interest payment amounting to $10.43 per ton. Usually high is the maintenance expense of $6.15 per ton. Reasons for this are included in the previous furnace wall and grate sections.

The sale of electricity was $5.59 per ton, a very consistent figure amoung plants that primarily sell electricity.

Counting the identified sources of revenue of $9.06 per ton, there results a net cost of $12.37 which is to be made up by other means.

TABLE L-22. OPERATIONS RESULTS FOR 1976 AT THE HAGUE

	Gl. per Tonne	U.S. 1976 % per Ton	Percent (%)
Operations	10.0	$ 3.73	17.4
Maintenance	16.5	6.15	28.7
Water use and Ash disposal	3.0	1.12	5.2
Principal and Interest	28.0	10.43	48.7
TOTAL EXPENSES	57.5	21.43	100.0%
Sale of Electricity	15.0	5.59	26.1
Monies from Private Haulers*	6.3	2.35	11.0
Monies from Suburban Communities*	3.0	1.12	5.2
Remainder from City of The Hague*	33.2	12.37	57.7
	57.5 Gl./Tonne	$ 21.43/Ton	100.0%

*The revenue received from each category is divided by the grand total refuse tonnage received. Thus, these figures are not to be confused with "tipping fees". Instead, the tipping fees are as follows:

Private Haulers	54 Gl./Tonne	$20.3/Ton
Suburban Communities	33 Gl./Tonne	$12.2/Ton
City of The Hague Public Vehicles	No direct assessment	

Dieppe

The accounting presentation for the Dieppe plant is very different from the other plants because this (and Deauville) is the only plant among the 15 studied in detail owned by private enterprise: As a private organization, they do not publish financial operating results.

Instead, they have provided Table L-23 which is detailed revenue schedule. It provides insight to communities considering the "private enterprise-full service" mode rather than "municipal ownership".

This is really a situation where the community supported the bonds and maintains basic ownership of the facility. In 1971, it was necessary for the plant to obtain additional equipment. It was decided that the operator Thermical-INOR would purchase the equipment out of company borrowed funds. This elimated the complexities of public refinancing. Instead it was agreed that the community would add an extra payment to cover the operator's loan as it matured monthly. This totaled 75,873 F.Fr. ($15,266) in 1976.

The revenue paid by the community for the refuse-sewage sludge activity is calculated in three parts for operations and also for maintenance activities. The fees include a fixed plus variable charge. The latter is a function of tonnes processed: there being 14, 892 tonnes in 1976.

Thermical - INOR is a joint venture wherein INOR, Von Roll's French licensee (of about 20 plants) contributes its skill in refuse burning to destroy sewage sludge. Thermical, however, contributes its skill in operations of the waste water treatment plant. it bills the community on a simple formula of 0.3189 F.Fr. per cubic meter ($0.000243 per gallon) of entering waste water. Thus the waste water treatment revenues in 1976 were:

1,740,190 m^3 of waste water
x0.3189 F.Fr. per m^3
554,946.59 F.Fr.

Thus the total Thermical - INOR income in 1976 was:

Waste water treatment	554,947
Refuse plus sewage sludge burning	1,366,099
	1,921,046 F.Fr.
or	$386,528

The City of Dieppe adjusts taxes annually to pay costs. The other participating towns pay Dieppe in proportion to the amount of waste water and refuse handled.

Private haulers pay 110 F.Fr./tonne ($19.09/ton) to Thermical-INOR to deliver refuse to the plant. Of this tipping fee, 8 F.Fr. are then paid by Thermical-INOR to the city to help retire the city's indebtedness.

Gothenburg

Operating results for 1976 are shown in Table L-24. Unfortunately, a clear and correct picture of the year's operation was not

TABLE L-23. ANNUAL INVOICE BILLINGS FROM THE CONTRACT OPERATOR THERMAL-INOR TO THE DIEPPE COMMUNITY FOR OPERATIONS AND MAINTENANCE (1976 RESULTS)

	French Francs	F.Fr. Per Year	F.Fr. Per Tonne	U.S. 1976 $ Per Ton	Percent (%)
Payments to INOR to amortize 1971 loan*	75,873	75,873	5.09	0.93	5.5
Fixed operating allowance	600,157				
Proportional operating allowance up to 14,000 tonnes	282,664				
Operating allowance for additional 892 tonnes	41,186				
TOTAL OPERATIONS ALLOWANCE		924,007	62.05	11.35	67.6
Fixed maintenance allowance	123,104				
Variable maintenance allowance up to 14,000 tonnes	44,979				
Maintenance allowance for additional 892 tonnes	5,041				
TOTAL MAINTENANCE ALLOWANCE		173,124	11.63	2.13	12.7
SUBTOTAL	1,173,004	1,173,004	78.77	14.41	85.8
Value added top of 17.6 percent of O & M	193,095	193,095	12.96	2.37	14.2
TOTAL (refuse and sewage sludge)	1,366,099	1,366,099	91.73	16.78	100.0

Example: $\frac{75{,}873\ \text{F.Fr.}}{1\ \text{Year}} \left(\frac{1\ \text{U.S. \$}}{4.970\ \text{F.Fr.}}\right) \left(\frac{1\ \text{Year}}{14{,}892\ \text{Tonnes}}\right) \left(\frac{1\ \text{Tonne}}{1.1\ \text{Ton}}\right) = \$0.93/\text{Ton}$

i.e., Multiply all F.Fr. numbers by .0000122828

*This 1971 loan is for a second crane, weigh station, furniture, one ash truck, several containers, a workshop, and some tools.

The large amortization is not shown on the Thermical-INOR schedule because the plant is owned by the community and not the company which has the O & M contract.

TABLE L-24. OPERATING RESULTS FOR 1976 AT GOTHENBURG

	Thousands of S.Kr. per year	S.Kr. per Tonne	U.S. 1976 $ Ton	Percent (%)
Machine repair and maintenance	2,100	8.66	1.91	6.9
Boiler-furnace repair	400	1.65	0.36	1.3
Building maintenance	300	1.24	0.27	1.0
Maintenance contracts (elev., crane)	100	0.40	0.09	0.3
Cleaning	300	1.24	0.27	1.0
Rent	105	0.43	0.10	0.3
Staff	3,000	12.37	2.72	9.9
Part-time workers	430	1.77	0.39	1.4
Electricity, water, oil	1,270	5.24	1.15	4.2
GRAAB management and administration	3,400	14.02	3.09	11.2
Estimated residue disposal cost	300	1.24	0.27	1.0
Interest	6,185	25.50	5.62	20.4
Depreciation	2,599	10.72	2.36	8.6
Known Expenses	20,489	84.48	18.60	67.6
Unexplained (??)	9,811	40.45	8.91	32.4
TOTAL EXPENSE	30,300	124.93	27.51	100.0
District heating and hot water sale	9,000	37.11	8.17	29.7
Tipping fees	21,300	87,82	19.34	70.3
TOTAL REVENUE	30,300	124.93	27.51	100.0

Example: $$\frac{2{,}100{,}000\ \text{S.Kr.}}{1\ \text{Year}} \left(\frac{1\ \text{U.S. \$}}{4.127\ \text{S.Kr.}}\right) \left(\frac{1\ \text{Year}}{242{,}536\ \text{Tonnes}}\right) \left(\frac{1\ \text{Tonne}}{1.1\ \text{Ton}}\right) = \$1.91/\text{Ton}$$

i.e., Multiply all S.Kr. numbers by .0000009082316 available. Either the revenue was overstated or an expense has been omitted amounting to 9,811,000 S.Kr.

An added one-time cost in 1976 was 3.5 million S.Kr. paid to the district heating system for a one-third share of the cost of 1.5 km heating line for a new hospital.

About 30 percent of the total revenues, $8.17 per refuse ton, comes from sale of hot water for district heating. The remaining 70 percent $19.35 per ton comes from tipping fees.

From 1972 to 1976, the standard tipping fee was held constant at 85 skr/tonne. For 1977, it was increased to 110 skr/tonne ($23.50/ton), and for ($31/ton), respectively. These high fees may be a reflection of the general concern in Sweden for environmentally clean waste disposal.

Uppsala

The operating results at Uppsala are reasonable at $17.62 per ton. See Table L-25. There appears also to be average interrelatorship among the expense categories with amortization and interest payments accounting for 37.16 percent of all expenses.

Unfortunately, at this writing, 1976 revenue figures are not available. Therefore 1975 figures are shown that have similar totals i.e. 1976 expenses of 4,163,000 S.Kr. compared with 1975 revenues of 4,591,000 S.Kr.

As expense category interrelationship categories are average, the revenue categories are most unusual---to the betterment of the taxpayers. Uppsala is both the northern most plant visited (1 hour north of Stockholm) and the plant with the highest energy revenue per refuse input ton. Steam sales were $11.70 per refuse input ton which equates to 63.12 percent of total revenues or expenses. Only $6.83 per ton needs to be charged taxpayers as a tipping fee or net disposal cost.

A plant official discussed the impact of future oil prices on the taxpayer's net disposal fee for refuse treatment. He presented Figure L-10.He hypothesized an OPEC oil price rise gradually to 1979 or 1980. Principal and interest payments would remain the same. Other costs would be subject o normal Swedish inflation. Total costs would rise from 80 S.Kr./tonne in 1976 to 90 S.Kr./tonne by mid 1979.

In November, 1975, the cost of oil delivered at the coastal terminal at Gavle was 350 S.Kr./tonne (about $12.69/barrel) Interest on the storage of 1 year's oil supply was 40 S.Kr. Tax was 50 S.Kr. Thus, the total effective oil cost then was 485 K/m^3 ($17.58/barel) By 1979, it was assumed for the calculation that the effective price of oil had risen to 600 S.Kr./tonne ($21.75/barrel). At that time the sale of steam would equal all costs and the tipping fee or taxpayer net disposal cost could be reduced to zero. Thus if the price of oil were to rise 24 percent, the refuse disposal cost could be eliminated.

We hasten to point out that the exercise was only the calculations of one person. We assume that the material has not been approved by management. Finally all should understnad that the simple exercise does not represent any system management's promise to eliminate tipping fees when oil prices increase 25 percent. There are too many other complicating factors.

TABLE L-25. OPERATIONS RESULTS AT UPPSALA FOR 1976 EXPENSES AND 1975 REVENUES

	Thousands of S.Kr. per year	S.Kr. per Tonne	U.S. $ per Ton	Percent (%)
1976 EXPENSES (52,040 Tonnes)				
Amortization and Interest (15 years, 10%)	1,547	29.73	$ 6.55	33.70
Staff Salaries and Wages	768	14.76	3.25	16.73
Fringe Benefits (Including Pension)	323	6.20	1.37	7.04
Repair and Maintenance	933	17.93	3.95	20.32
Building Maintenance and Cleaning	80	1.54	0.34	1.74
Electricity Consumption	280	5.38	1.18	6.10
Administration	232	4.46	0.98	5.05
TOTAL 1976 OWNING AND OPERATING COST	4,163	80.00	$ 17.62	90.68
Contribution to reserves	428	8.22	1.81	9.32
TOTAL 1976 REVENUES	4,591	88.22	19.43	100.00
1975 REVENUES (51,355 Tonnes)				
Steam Sales	2,898	56.43	11.70	63.12
Tipping Fees	1,693	32.97	6.83	36.88
TOTAL 1975 REVENUES	4,591	89.40	18.53	100.00

Example:
$$\frac{1{,}547{,}000\ \text{S.Kr.}}{1\ \text{Year}} \left(\frac{1\ \text{U.S. 1976 \$}}{4.127\ \text{S.Kr.}}\right)\left(\frac{1\ \text{Year}}{52{,}040\ \text{Tonnes}}\right)\left(\frac{1\ \text{Tonne}}{1.1\ \text{Ton}}\right) = \$6.55/\text{Ton}$$

i.e., Multiply all Expense numbers by .0000042328

Example:
$$\frac{2{,}898{,}000\ \text{S.Kr.}}{1\ \text{Year}} \left(\frac{1\ \text{U.S. 1975 \$}}{4.386\ \text{S.Kr.}}\right)\left(\frac{1\ \text{Year}}{51{,}355\ \text{Tonnes}}\right)\left(\frac{1\ \text{Tonne}}{1.1\ \text{Ton}}\right) = \$11.70/\text{Ton}$$

i.e., Multiply all Revenue numbers by .000004036

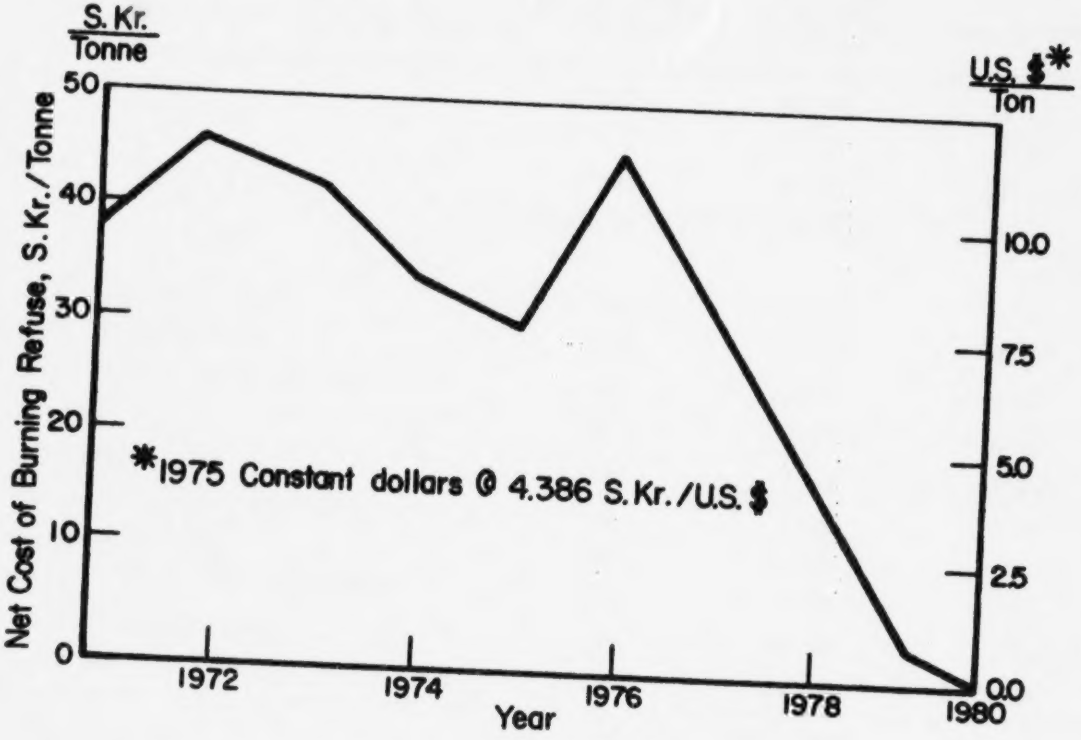


FIGURE L-10. PAST AND PREDICTED TREND OF NET OPERATING COST OF REFUSE BURNING PLANT AFTER CREDIT IS TAKEN FOR THE VALUE OF HEATING RECOVERED

Table L-26 shows the projected operating budget for 1977 and 1978 which is evidently based on the experience of previous years. A major increase of expense for 1978 will be the added amortiation cost for the new 1.8 Km (1.1 mile) pipeline to the older private district heating system. The expected effect is a substantial increase in annual cost that are more than offset by a tripling in revenues.

Copenhagen:Amager

Annual costs and revenues are distributed as shown in Table L-27.

Depreciation and interest account for the largest expenses at 42.45 percent or $9.50 per ton.

Amager results include operations not only at the refuse fired steam generator but also activities at the adjoining transfer station and the distant landfill. An unusual expense is government taxes since the plant is owned by a unit of government. In total, these expenses total 16.19 percent of total expenses.

On the revenue side, transfer station and landfill tipping fees, interest earned on current assets and excess office space rent total 12.47 percent of total revenues. Apparently, the refuse - energy plant partically subsidises transfer station and landfill operations by about $1 per ton.

The tipping fees and the general head tax provide most of the revenue. The revenue from district heating, originally planned to be 2,200,000 D.Kr. in this year, actually turned out to be more than double that at 4,878,000 D.Kr. By definition of a "not-for-profit organization", the expenses must equal revenues. In this case, they are both equal to 36,305,000 D.Kr.

Because tipping fees and the heat tax is substantial, monies were set aside for a future ash processing plant. Also $1.29 was returned to the asset account.

Table L-28 presents the annual costs and revenues per tonne for almost 5 fiscal years. Note that increased revenues from the sale of heat have offset increases in operating costs so that the net cost to the taxpayer has remained relatively steady for 5 years.

Revenues from tipping fees and community head taxes totaled $11.59 per ton or 64.75 percent of total revenues in 1976. Sale of hot water for district heating was $6.78 per ton or 24.17 percent of total revenues. The detachable containers placed near the plant entrance before the scales yielded $.15 per refuse input ton or 52 percent.

An unusual source of revenues was $2.58 per ton or 9.22 percent of revenue for interest earned. Apparently the system collects revenues prior to incurring expenses and loan payments. This cash is invested at the bank and in short term securities.

Copenhagen:West

As with most preceeding plants, the largest expense items are depreciation and interest amounts to $13.52 per ton or 48.21 percent. The operating personnel costs t $3.20 per ton appear most reasonable as does maintenance costs at $1.08 per ton.

TABLE L-26. OPERATING BUDGET FOR HORSENS PLANT, 1977-1978 (COURTESY OF CITY OF HORSENS, MR FINN LARSEN)

	Budget 1977, Dkr	Budget 1978, Dkr
Expenses		
Administration	70,650	91,900
Staff salaries and benefits	732,600	971,650
Utilities and supplies	359,000	452,000
Property taxes, building repairs, maintenance	103,000	107,170
Residue hauling, truck maintenance, repair	14,000	14,730
Residue tipping costs	6,000	9,000
Tools	20,000	29,060
Equipment maintenance, repair, including outside labor	280,000	321,000
Administrative supplies, advertising	14,000	16,650
Chemical analysis	5,000	5,250
Amortization of principal, interest	786,200	1,904,300
Total Operating Expense	2,390,450	3,922,710
Income		
Fees from Geved community	130,000	150,000
Tipping fees (industrial waste)	368,000	410,000
Sludge dewatering, drying fee	246,000	442,000
Sale of heat	0	1,327,000
Total Income	744,000	2,329,000
Net Operating Cost	1,646,450	1,593,710
Number of households	16,700	17,115
Net cost per household	98.59	93.12

TABLE L-27. ANNUAL COSTS AND REVENUES AT COPENHAGEN:AMAGER
(In D.Kr./Tonne)

	1972-1973	1973-1974	1974-1975	1975-1976	1976 (9 mo.)
Tonnes Burned	200,000	226,000	224,000	255,000	190,000
Wages	12.14	14.04	18.34	19.72	20.99
Operation Expenses	5.84	5.97	9.42	8.61	9.77
Clinker Disposal	2.17	2.26	2.72	3.01	3.38
Administration	2.72	2.70	3.48	3.67	4.25
Maintenance Expenses	3.74	5.92	12.35	9.47	11.25
Taxes and Insurance	3.87	4.06	4.17	3.99	4.43
Operations and Maintenance	30.48	34.95	50.48	48.47	54.07
Interest Expense on Loans	39.45	38.01	35.44	29.12	36.00
Depreciation	36.36	32.73	39.29	31.37	31.58
Total Cost	106.29	105.69	125.21	108.96	121.65
Revenue From Energy Sale	7.00	9.22	19.10*	19.13	18.23
Net Operating Income	99.29	96.47	106.11	89.83	103.42
Revenue From Interest	-	0.56	4.48	3.99	6.59
Revenue From Rent and Transfer Services	1.10	0.94	1.09	0.96	0.96
Net Cost	98.19	94.97	100.54	84.88	95.87

*Dramatic year-to-year rise in income from sale of heat due to the oil crisis.

TABLE L-28. OPERATIONS RESULTS AT COPENHAGEN:AMAGER (REFUSE TO ENERGY AND LANDFILL) PLANT, TRANSFER STATION

	D.Kr.Per Year	D.Kr.per Tonne	U.S. 1976 $/Ton	Percent(%)
Operational Salaries	5,028,000	19.72	3.10	13.85
Other Operation Expenses	2,196,000	8.61	1.35	6.05
Ash Disposal Expenses	769,000	3.00	.47	2.12
Transfer Station Expenses	4,008,000	15.72	2.47	11.04
Landfill Operation Expenses	853,000	3.35	.52	2.35
Administrative Expenses, Meetings	197,000	.77	.12	.54
Administrative Salaries	514,000	2.02	.32	1.42
Other Administrative Expenses	224,000	.88	.14	.62
Plant Maintenance	2,415,000	9.47	1.49	6.65
Government Taxes and Other Fees	1,018,000	3.99	.63	2.80
Interest on Loan	7,425,000	29.12	4.57	20.45
Depreciation on Plant	8,000,000	31.37	4.93	22.03
TOTAL EXPENSES	32,647,000	128.03	20.11	89.92
Account Set Aside to Build an Ash Transportation Plant	1,566,000*	6.14	.96	4.31
Surplus Returned to Asset Account	2,093,000	8.21	1.29	5.77
GRAND TOTAL	36,306,000	142.38	22.36	100.00
Communities' Tipping Fee at 40 Dkr/Tonne	7,872,000	54.03	4.85	21.68
Government (?) Tipping Fee at 40 Dkr/Tonne	169,000	.66	.10	.40
Private Haulers' Tipping Fee at 40 Drk/tonne	2,423,000	9.50	1.49	6.67
Head Tax at 30 Dkr/year	16,441,000	64.47	10.13	45.28
Revenue from Energy Sale to District Heating Network	4,878,000	19.13	3.00	13.44
Transfer Station Tipping Fee (?)	2,743,000	10.76	1.69	7.56
Landfill Tipping Fee	515,000	2.02	.32	1.42
Interest Earned on Current Assets	1,019,000	4.00	.63	2.81
Rent of Excess Office and Filing Space	246,000	.96	.15	.68
TOTAL REVENUES	36,306,000	142.38	22.36	100.00

Example: $\frac{5{,}028{,}000\text{ D.Kr.}}{1\text{ Year}} \left(\frac{1\text{ U.S. \$}}{5.788\text{ D.Kr.}}\right) \left(\frac{1\text{ Year}}{255{,}000\text{ Tonnes}}\right) \left(\frac{1\text{ Tonne}}{1.1\text{ Tons}}\right) =$

i.e., Multiply all D.Kr. numbers by .00000061594

TABLE L-29. OPERATIONS RESULTS AT COPENHAGEN:WEST (VEST) FOR 1975-1976

	D.Kr. per Year	D.Kr. per Tonne	U.S. 1976 $ per Ton	Percent(%)
Operating Personnel Cost	4,766,827	20.35	3.20	11.40
Electricity	1,997,539	8.53	1.34	4.78
Materials	108,165	.46	.07	.26
Cooling Water	141,348	.60	.09	.34
Canteen	178,738	.76	.12	.43
Other Utilities	29,581	.13	.02	.07
Ash Recovery and Disposal	1,082,522	4.62	.72	2.59
Expense to Operate Various Landfill	127,275	.54	.08	.30
Research	515,324	2.20	.35	1.23
Expenses of Assembly and Board of Directors	210,411	.90	.14	.50
Sálary of Nine Administrators	667,721	2.85	.45	1.60
Office Supplies	475,811	2.03	.32	1.14
Maintenance Costs	1,614,145	6.89	1.08	3.86
Property Taxes and Insurance	1,008,264	4.3	.68	2.41
Expenses of Running the District, Heating Network and Standby Boiler	1,262,680	5.39	.85	3.02
Depreciation of District Heating Network	1,400,000	5.98	.94	3.35
Interest Paid on Loan made by Gentofte, Lyngby-Taarback	1,925,743	8.22	1.29	4.61
Interest Paid on Loan made by Glostrup and Ballerup for Construction of Four Furnaces	86,490	.37	.06	.21
Interest Paid on Other Borrowings (?)	7,305,954	31.19	4.90	17.47
Depreciation (?)	11,453,037	48.90	7.68	27.39
Other Expenses, West Incinerator Partial Pension to Staff of the Old Gentofte Incinerator	24,814	.11	.02	.06
Put Aside Money for the Partial Financing of Expenses to the Case of Lesser Installation Work?	5,426,307	23.17	3.64	12.98
TOTAL EXPENSES	41,809,696	178.50	28.04	100.00
Communities (12) Tax Based on Tonnes Disposed	7,759,726	33.13	5.20	18.56
Other Waste Disposal Fees (Institution, Private Haulers, Industry)	2,029,734	8.67	1.36	4.85
Communities (12) Tax Based on Population	17,279,880	73.77	11.59	41.33
District Heating Revenue	10,106,524	43.15	6.78	24.17
Sale of Sorted Materials	219,300	.94	.15	.52
Typing Fee at Old Landfill	370,660	1.58	.25	.89
Interest Earned	3,855,745	16.46	2.58	9.22
Other Revenue	188,127	.80	.13	.45
TOTAL	41,809,696	178.50	28.04	100.00

Example: $\frac{4,766,827\ \text{D.Kr.}}{1\ \text{Year}} \left(\frac{1\ \text{U.S. \$}}{5.78\ \text{D.Kr.}}\right) \left(\frac{1\ \text{Year}}{234,230\ \text{Tonnes}}\right) \left(\frac{1\ \text{Tonne}}{1.1\ \text{Ton}}\right) = \$\ 3.20/\text{Ton}$

i.e., Multiply all D.Kr. numbers by .00000067056 to obtain 1976 U.S. $/Ton.

Despite this being a not for profit public service organization, property taxes are paid.

Of note are the loan repayments to groups of communities. The reader is encouraged to review the Finance chapter discussion. Perhaps neighboring American communities can loan funds to the plant's host city.

Finally, after all revenues and expenses have been accounted for, there is a "put aside" amounting to 13 percent of the total.

Finance General Comments

Table L-30 presents modes of financing. There was no real financial pattern between countries. In all cases, the plants were built and financed and are owned by the municipality or solid waste authority. This includes Issy, operated by T.I.R.U. but owned by the City of Paris and also Dieppe operated by I.N.O.R.-Thermical and owned by the City of Dieppe.

Interestingly this municipally controlled financing is in contrast to the latest (starting in 1974) fashionable practice in the U.S. of private enterprise ownership and finance. John Kehoe of Wheelabrator-Frye has been a leader toward private financing as compared with publicly controlled financing.

The availability of tax free bonding for private enterprise to develop public service environmental services will continue to affect not only detailed financing decisions but also basic decisions about ownership and operations.

Of note was that the vendor VKW at Wuppertal and I.N.O.R. (Von Roll) at Dieppe made modest company loans to the customer for purchase of scrubbers, a crane, a weigh station, furniture, an ash truck, etc. None of that which was financed was a "manufactured product" of these two companies.

The only relatively common mode (7 plants out of 15) of finance was to use the bank loan.

The detailed financial structure of the 15 plants visited is presented in Table L-31.

Finance Comments About Visited Systems

Werdenberg-Liechtenstein

Based on a Swiss law passed during the early 1970's financing was achieved from banks and the three levels of government as follows:

Grant from Government of Switzerland and EPA (Amt fur Umweltschutz)
State of St. Gallen Water District (Gewasserschutzamt)
Country of Liechtenstein
Bank Loans

The bank loan was for 15 years at 9 percent.

Baden-Brugg

The total cost of the plant (16,500,000 S.Fr. ($6,650,000) was financed by a regular bank loan of 10.4 million S.Fr. plus joint financing

TABLE L-30. MODES OF FINANCE FOR EUROPEAN REFUSE-ENERGY PLANTS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	Werdenberg-Liechtenstein	Baden-Brugg	Duesseldorf	Wuppertal	Krefeld	Paris: Issy	Hamburg: Stellinger-Moor	Zurich: Hagenholz	The Hague	Dieppe	Gothenburg	Uppsala	Horsens	Copenhagen: Amager	Copenhagen: West	Total Mentions
Internal Reserve General Funds										X			X			2
Internal Special Building Reserve Funds							X	X					X			3
Public Electric Utility Company Equity Funds																0
District Heating System Company Equity Funds												X				1
Regular Bank Loan	X	X		X			X	X	X					X	X	8
Pension Fund Loan											X					1
General Obligation Bond (Investor Market)						X							X			2
Revenue Bond (Investor Market)																0
State Government Loan										X						1
State Government Grant	X	X		X												3
Federal Government Loan				X				X		X						3
Federal Government Grant	X	X								X						3
System Developer Loan				X						X						2
Neighborhood City Loans				X										X	X	3

TABLE L-31. FINANCIAL STRUCTURE OF 15 EUROPEAN REFUSE-FIRED ENERGY PLANTS

System		Year of Financing	Year of Beginning Operation	Source and Financing Mode	Loan or Grant	Years of Term	Interest Rate	Tax Exempt	Amount Local Currency	U.S. $ in Year of Financing
Werdenberg-Liechtenstein	1			Regualr Bank Loan	Loan			Exempt	10,400,000 S.Fr.	
	2			Canton (State) of Aargau					3,500,000 S.Fr.	
	3			Federal Govt. of Switzerland					2,500,000 S.Fr.	
	Total						5.5-6.0		16,500,000 S.Fr.	
Baden-Brugg	1									
	2									
	3									
	4									
	Total									
Duesseldorf	1									
	2									
	3									
	4									
	Total									
Wuppertal	1		1975	State Grant (N. Rhein-Westphalia	Grant				24,000,000 D.M.	
	2			Municipal Savings Bank	Loan				40,000,000 D.M.	
	3			Federal Bank	Loan				20,000,000 D.M.	
	4			Vereinigte Kesselwerke	Loan				12,000,000 D.M.	
	5			Commercial Loan (Scrubbers)	Loan				12,000,000 D.M.	
	6			Commercial Loan (Pay VKW)	Loan				12,000,000 D.M.	
	7			Prefinancing from Cities of Wuppertal & Remscheid	Grant				6,000,000 D.M.	
	Total								126,000,000 D.M.	
Krefeld	1									
	2									
	3									
	4									
	Total									

TABLE L-32. FINANCIAL STRUCTURE OF 15 EUROPEAN REFUSE-FIRED ENERGY PLANTS

System		Year of Financing	Year of Beginning Operation	Source and Financing Mode	Loan or Grant	Years of Term	Interest Rate	Tax Exempt	Amount Local Currency	U.S. $ in Year of Financing
Paris: Issy	1	1964		City of Paris Larger General Obligation Bond Solid to Insurance Cos.	Loan	20	6.5– 8.0 Varing	Exempt	110,000,000 F.Fr.	
	Total								110,000,000 F.Fr.	
Hamburg:Stellinger-Moor	1			City's Gneral Fund	Grant	20				
	2			Local Bank Loan	Loan	Varing				
	Total									
Zurich:Hagenholz	1			City of Zurich (Funds) 70%	Mixed	5	4.5–4.75			
	2	1973		Local Bank Loan	Loan					
	3			Kanton (State) of Zurich 15%	Grant					
				Federal Govt. of Switzerland 15 %	Grant					
	Total									
The Hague	1				Loan	25				
	2									
	3									
	4									
	Total									
Dieppe	1		1970	State Debentures	Loan	30			2,170,000 F.Fr.	
	2			Federal Grants	Grant				3,202,528 F.Fr.	
	3			French National "Caisse des Deports"	Loan		4.5		5,000,000 F.Fr.	
			1970	City of Dieppe Tax Reserve	Grant				1,000,000 F.Fr.	
									11,372,528 F.Fr.	
	4	1971	1971	Advanced by INOR the Von Roll Licensee and Operator (Misc. Equipment)	Loan	20			700,000 to 800,000 F.Fr.	
	Total								12,000,000 F.Fr.	

TABLE L-33. FINANCIAL STRUCTURE OF 15 EUROPEAN REFUSE-FIRED ENERGY PLANTS

System		Year of Financing	Year of Beginning Operation	Source and Financing Mode	Loan or Grant	Years of Term	Interest Rate	Tax Exempt	Amount Local Currency	U.S. $ in Year of Financing
Gothenberg	1	1969		Communitites Contribution	Grant				4,500,000 S.Kr.	
	2			A Major Pension Fund	Loan	20	7.3 Adjustable after 10 yrs.		90,000,000 S.Kr.	
	Total									
			1972	Other Borrowings Loan					120,000,000 S.Kr.	
Uppsala	1			Commercial Lending Sources	Loan				3,400,000 S.Kr.	
	2			District Heating System Reserves	Grant				6,700,000 S.Kr.	
	3			Other					950,000 S.Kr.	
	Total								11,050,000 S.Kr.	
Horsens	1		1973	City of Horsens Reserves	Grant				11,074,423 S.Kr.	
	2		1973	Bonds (what kind?)	Loan					
	3			Other Financing					7,000,000 S.Kr.	
	Total								18,000,000 S.Kr.	
Copenhagen:Amager	1			The Cities Put in Reserves and Obtained Loans based on Population	Mixed	Variable Average	8			
	2			Local Bank	Loan					
	Total									
Copenhagen:West	1			Twelve Cities Put in Reserves and Obtained Loans based on Population	Mixed	Variable Average	8			
	2			Local Bank	Loan					
	Total									

of the 6.1 million S.Fr. remainder by Federal and Cantonal grants in the amount of 2.5 million S.Fr. from the Federal Government and 3.5 million S.Fr. by the canton of Aargau.

The interest on the debt ranges from 5.25 to 6 percent and the loan is tax exempt. As of 1977, the original loan of 10.4 million S.Fr. has been reduced to 6.6 million S.Fr.

Wuppertal

The plant cost 126,000,000 DM ($48,000,000) in 1975. This was financed as follows:

	Millions of 1975 DM	Millions of 1975 $
State Grant (N. Rhein - Westphalia)	24	9.2
7.5%, 18-yr loan, Municipal Savings Bank	40	15.3
6%, 18-yr loan, Federal Bank	20	7.7
7%, 4-yr loan, Vereinigte Kesselwerke	12	4.5
Commercial loan to be arranged for scrubbers	12	4.5
Commercial loan for final payment to VKW	12	4.5
Prefinancing from cities of Wuppertal, Remscheid	6	2.3
Total	126	48.0

Paris: Issy

The 110,000 Frfr ($22,450,000) was financed by the City of Paris' larger general obligation bond sold to insurance companies and other large investors. Payments on the 20-year bond began in 1964 at a 6.5 percent interest rate. The rate has fluctuated and is currently 8 percent.

Hamburg: Stellinger-Moor

Funds not accumulated in the City of Hamburg's general funds were borrowed from local banks. Plant life was estimated to be 20 years and presumably some of the loans were for that period of time. In 1976, the city paid 1,166,000 DM ($466,400) as principal and interest.

Zurich: Hagenholz

The original 1969 development of 56 million S.Fr. ($12,970,000) was financed by three sources of funds as follows:

70% by the City of Zurich
15% by the Kanton (state) of Zurich
15% by the Federal Switzerland Government

The City of Zurich for its 70% portion put up cash on hand and also borrowed money from local banks as general obligation bonds. Usually the term is five years. The interest rate varies. Having started at 4-1/2% in 1973 for Unit #3, it was 4-3/4 in 1976. The building is amortized over 25 years and the mechanical equipment is amortized in 14 years.

Borrowing from the Swiss Federal Government carries a small but important risk. The only way that the Federal funds will be released to the City is after the plant has been built and the environmental portion of the compliance test has been successfully passed.

At Hagenholz, the acceptance test was run after 4,000 hours and before cleaning to ensure performance even under adverse conditions. As was stated, and we paraphrase again, "Anyone can make a unit be acceptable immediately after cleaning. The trick is to make it acceptable after a half year's operation with no cleaning and overhaul".

Nashville. Had the Nashville, Tennessee, system been built under such a financial scheme, the Federal funds for the plant built basically in 1973 would have been released, half in 1976 and half in 1977. These are the dates for retrofit completion with electrostatic precipitators. But this may only be academic. Had such a financing scheme been in effect, local officials may not have taken the gamble with low energy water spray scrubbers.

The Hague

All of the funds needed to build the plant were borrowed by the city on a 25-year loan within uniform payment and declining balance. The equipment life is estimated at 25 years, building at 40 years.

Dieppe

The total cost of 11,380,000 F.Fr. ($2,061,000) was financed in 1970 as follows:

	French Francs	1970 U.S. Dollars
State 30-year Debentures	2,170,000	393,000
Federal Grants	3,202,528	580,000
Borrowed from National "Caisse des Depots"	5,000,000	906,000
Dieppe Tax Reserve	1,000,000	182,000
TOTAL	11,372,528	2,061,000

The loan from Caisse des Depots was a 30-year loan at 4.5 percent.

In 1971, additional purchases were made of a second crane, weigh station, furniture, ash truck, refuse containers, and workshop and tools for about 700-800 F.Fr. This money was advanced by INOR to be paid back over 20 years at an annual charge for principal and interest of 75,873 F.Fr. ($14,591).

Gothenburg: Savenas

The cost of the system in 1972 was about 120 million S.Kr. ($25,300,000). In 1969, the communities represented in GRAAB raised 4.5 million S.Kr. ($949,000). On the basis of this commitment, GRAAB borrowed 90 million S.Kr. for 20 years from a major pension fund at 7.3 percent interest. After 10 years, this interest can be adjusted depending on interest trends at that time. Communities which borrow such large sums must first have approval of the Swedish Government.

Because the final cost of the system nearly doubled over the early estimates, additional money was borrowed on similar terms in order to complete construction.

Uppsala

Of the total 11.05 million S.Kr. ($2,763,000 @ 5 S.Kr./$) original capital cost, 3.4 million S.Kr. was borrowed from commercial lending sources. An additional 6.7 million S.Kr. was financed from reserves from previous operations of the heating system. Out of present operations, it is planned to build up a reserve for the community of about 3 million S.Kr.

The refuse burning plant is to be amortized over 15 years at a nominal interest rate of 10 percent. Plant staff remarked that they would find it difficult to imagine operating the facility as a private enterprise.

Horsens

The initial plant cost in 1973 of 11,094,423 D.Kr. was self-financed out of bonds and reserves. In future financing, the plan is to build up the reserves again to the point that private borrowing can be avoided because the interest rates for such money is not 18 percent. If community reserves are used, the internal opportunity interest cost is about 10 to 12 percent.

At present, the total Horsens community budget is 225 million D.Kr. About half of that is spent for education. Thus, the 18 million D.Kr. spent so far for the waste-to-energy system is a relatively small item. In presenting the project to the public, it was estimated that it would involve a daily per-capita cost of about 1.5 D.Kr./day (25 cents/day). The new wastewater treatment plant costs about the same. The citizens readily accepted this cost of a cleaner environment which daily totaled less than the 12 to 14 D.Kr. ($2.00 to $2.33) cost of a pack of cigarettes!

Copenhagen: Amager and West

The financial arrangements were straightforward. The 12 municipalities put in money based on population. The remainder was borrowed at local banks. The payoff period is variable as well as the interest rate that has averaged about 8 percent.

ORGANIZATION AND PERSONNEL

The section on organization and personnel is organized into the following parts.

- System Ownership and Governing Patterns
- Personnel Categories
- Education, Training and Experience
- Organization and Personnel at Visited Systems

System Ownership and Governing Patterns

Private enterprise owned none of the 30 systems visited. In all cases solid waste disposal and resource recovery are public matters. Of the 15 plants studied in detail, operation was turned over by the City of another organization twice.

Paris: Issy, while owned by the City of Paris is operated by T.I.R.U., a subsidiary of the Federal utility, Electricitie de France. Secondly, the City of Dieppe has given an operations contract to the Von Roll French licensee, I.N.O.R. Interestingly, the only privately operated plants out of 15 visited are in France.

The total pattern of ownership is presented in Table M-1. Cities own 8 plants while public authorities own 6 plants.

The number of communities served varies extensively. The small Werdenberg 132 ton per day single-line plant has 76 delegates to the annual Society for Refuse Management meeting: one delegate per 1000 people served. Paris: Issy's M. Defeche would likely report to one executive within the very large Electricitie de France.

Personnel Categories

Over 120 job titles are to be found in the fifteen trip reports. Many are duplicative as exemplified below:

- Maintenance worker
- Repair crew
- Artisan
- Relief maintenance.

To provide a meaningful list of possible jobs, these job titles have been collapsed into 55 personnel categories as shown in Table M-2. In no way is it recommended that any plant have all of these jobs. This table is presented simply as a shopping list or check list of possibilities.

The previous Economics Section mentioned that there is little economy of scale in refuse to energy plants because of a tendency to add optional equipment to the larger plants. Similarly, planners for larger plants believe that they can afford more personnel.

Werdenberg-Liechtenstein, processing 132 tons per day, has a plant manager, an assistant, and a bookkeeper, who is the manager's wife. Wuppertal, however, at 1,440 tonnes (1,584 tons) design and 624 tonnes (686 tons) actual per day has the following executive categories:

Commercial Manager
Commercial Supervisor

TABLE M-1. OWNERSHIP/GOVERNING PATTERNS

Trip		Ownership Pattern	Number of Communities	Number of Persons on Board
1	Werdenberg-Liechtenstein	Authority		76
2	Baden-Brugg	Authority		
3	Duesseldorf	City		
4	Wuppertal	Authority	2	12
5	Krefeld	City		
6	Paris:Issy	Federal Utility*	54	
7	Hamburg:Stellinger-Moor	City		
8	Zurich:Hagenholz	City		
9	The Hague	City		
10	Dieppe (and Deauville)	City Owned/Privately Operated		
11	Gothenburg	Authority		
12	Uppsala	City		
13	Horsens	City		
14	Copenhagen:Amager	Authority	5	18
15	Copenhagen:West	Authority	12	70

TABLE M-2. PERSONNEL CATEGORY LISTING FOR REFUSE FIRED ENERGY PLANTS

- Administrative/Engineering (Often Downtown)
    - Board Members/Directors/Delegates/Councilmen
    - President/Chief/Director
    - Financial/Commercial Manager
    - Technical/Engineering Manager
    - Personnel Manager
    - Public Relations Manager
- Office Functions
    - Data Processing Supervisor
    - Accounting Supervisor
    - Technical Consultant
    - Construction Engineer
    - Plant Engineer
    - Landfill Engineer
    - Office Supervisor
    - Economist
    - Purchasing Agent/Buyer
    - Secretary
- Management (Always at the Plant)
    - Plant Manager
    - Operations Supervisor
    - Maintenance Supervisor
    - Shift Foreman
- Routine Cleaning
    - Janitor/Office Cleaner
    - Plant Cleaner
- Refuse Control and Handling
    - Gate Guard
    - Scale Operator
    - Shear/Shredder Operator
    - Tipping Floor Controller/Sweeper
    - Crane Operator

TABLE M-2. (Continued)

- Energy Production Operations
  - Furnace/Boiler Room Operator
  - Turbine Room Operator
  - Standby Boiler Operator
  - Control Room Operator
- Maintenance
  - Boiler Cleaner
  - Brick Layer
  - Electrician/Meter and Control Technician
  - Greaser
  - Laborers
  - Machinist
  - Mechanic
  - Pipefitter
  - Repair Crew
  - Tool and Parts Storeroom Clerk
  - Welder
  - Relief/Reserve/Vacation Replacement Maintenance Worker
- Ash Handling and Recovery
  - Discharge Mechanic
  - Crane Operator
  - Truck Driver
  - Reclamation Operator
- Special Operations
  - Lawn Care/Landscaper
  - Pathological/Hospital Waste/Dextrose Incinerator Operator
  - Sewage Sludge Processing Operator
  - Canteen Lady
  - Waste Water Treatment Plant Operator
  - Waste Oil Solvent Receptor and Processor
  - Hazardous Waste Receptor and Transfer

Technical Manager
Technical Supervisor
Financial Manager
Personnel
Purchasing
Assistant to the Commercial Supervisor
Data Processing
Accounting
Operations Economics
Chief Engineer

Potential economics of scale from the larger plant are nullifed by a large staff. This observation holds true not only for managerial functions but also operations personnel. One example is the chemical worker at Duesseldorf.

The above is not mentioned as criticism. Perhaps the technican worker is necessary. Looking back to the Nashville, Tennessee unit, if excessive scale build up inside the tubes would have been detected earlier. Instead, scale built up until major tube sections burst, causing may thousands of dollars of damage and downtime. The damage cost could have equaled a chemical analyst's salary for several years. They now have an analyst.

Battelle is not arguing that every plant should necessarily have a analyst. Only one of 15 plants surveyed had an employee analyst. Many others used outside testing laboratories. This leads to another personnel point.

Rather than hire permanent employees, many plants use outside services extensively. Some common services are shown in Table M-3. This is practiced extensively in Zurich.

Education, Training and Experience

Training varies widely among countries. Germany seems to have the most vigorus program. This usually involves schooling, navy or merchant marine boiler room experience, more schooling, more sea experience, etc. for up to 16 years. Often between ages 30 and 40, the man will leave the sea to become a stationary power boiler operator. Eventually he moves to a refuse fired energy plant.

Switzerland, a land locked nation often uses former employees of Brown Bovari, Sulzer, etc. who formerly made or installed boilers around the world. Max Baltensperger of Zurich perfers extensive on the job training.

Organization and Personnel at Visited Systems

Werdenberg-Liechtenstein

Seventy-six (76) delegates are chosen (one for each 1000 inhabitants) to represent them on the Vereins fur Abfallbeseifigung (Society for Refuse Management). These 76 delegates elect an operating Board of Directors. The Board of Directors hires the Plant Manager, who turn, hires the remainder of the staff.

The plant is managed by Robere Giger and his assistant. The Plant Manager's wife performs bookkeeping and secretarial duties as a part-time employee. The plant operates 5 days per week with only two operators on each

TABLE M-3. OUTSIDE CONTRACTED SERVICES FREQUENTLY USED

1. Janitorial Office Cleaning
2. Boiler Cleaning
3. Brick Laying
4. Pipefitting/Boiler Repair
5. Ash Processing and Recycling
6. Canteen or Cafeteria Service
7. Air Pollution Compliance Testors
8. Welding/Mechanical Work/Plumbing, etc.
9. Lawncare/Landscaping
10. White Goods/Electric Motor/Tire etc., Recycling
11. Meter and Control Instrument Calibration

of three shifts plus a weight-scale operator in the day shift. A "fourth shift" exists for vacation and sick leave replacement. In addition to the refuse fired steam generator building activity, the two managers are responsible for the compost plant and the separate Incinerator I - now the community's pathological incinerator.

Figure M-1 shows the organization for the RFSG only. During weekends, when only the standby oil boiler is fired, one of the shift bosses must be ready to respond to an automatic alarm in his home. In other words, the plant produces hot water, steam, and electricity continuously on weekends - but with no personnel routinely on duty.

Approximate monthly take-home pay is as follows:

- General Manager - 3500 Sw Fr. ($1400)
- Shift Boss - 2600 Sw Fr. ($1040)
- Crane Operator - 2500 Sw Fr. ($1000)

Vacations are given in accordance with the age as follows:

- Age under 45 - 3 weeks
- Age 45-50 - 4 weeks
- Age 50+ - 5 weeks

The shift boss is expected to have a Federal icense as a mechanic or electramechanic.

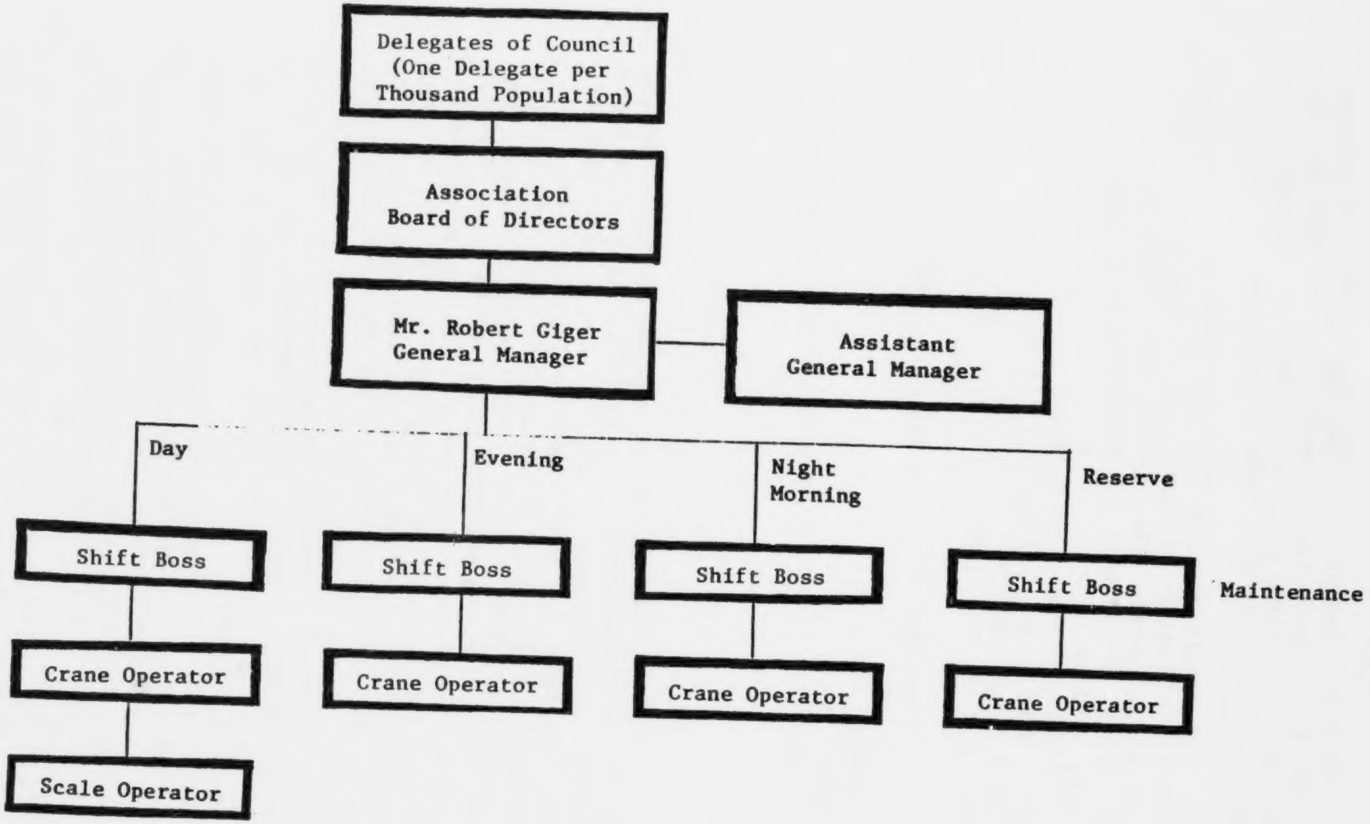
Baden-Brugg

The plant is owned and operated by the Zweckverban Kerichtverwertung Baden-Brugg. The president of the organization, Dr. Zumbuhl, hires the Plant Manager, who in turn, hires the remainder of staff. The governing board (Vorstand) and council meet about twice per year to make major decisions.

The plant now operates 5 days per week with only three operators on each of three shifts plus a standby operator. The Plant Manager, E. Leudi, has an assistant. The administrative and maintenance stafff works 5-1/2 days (44 hours) per week. One maintenance worker is full-time and three others are part-time. When not working on maintenance these men can fill in on other jobs. In January 1978 the plant was to have begun a 7-day week operation. The total plant staff is now 18 and the manager indicated there should be more. The manager is also responsible for the operation of the adjacent sewage plant. Total wages and salaries for 1976 were 825,163.65 Sw Fr ($332,541). This is an average of $1535 per worker per month. Benefits in addition were 108,475.55 Sw Fr ($43,716) per year. An extensive annual report is prepared with the assistance of local government accountants.

Each of the plant staff receives brief training except the scale operator and custodian. No federal boiler operator's licese is required. This plant has a unique source of skilled personnel in that the world headquarters of the Brown-Boveria Company is located in Baden. Hence three of the current shift foremen have had extensive prior experience in building and assembling heavy power-generating machinery.

New workers are first assigned to the assistant plant manager for 3 or 4 days per week to become familiar with the overall plant. Then they are gradually transferred to work along side the current operator on the job to which they will be assigned. After 4 or 5 weeks they are expected to be able


Delegates of Council
(One Delegate per
Thousand Population)
Association
Board of Directors
Mr. Robert Giger
General Manager
Assistant
General Manager
Day
Evening
Night
Morning
Reserve
Shift Boss
Shift Boss
Shift Boss
Shift Boss
Maintenance
Crane Operator
Crane Operator
Crane Operator
Crane Operator
Scale Operator

Shift Boss

1. Controls plant
2. Drives furnace
3. Water analysis
4. Control room
5. Equipment inspections
6. Repairs (minor)

Crane Operator

1. Drives crane
2. Substitute Scale Operator
3. Substitute Control Room

Reserve

1. Vacation replacement
2. Major repairs
3. Shift boss replacement
4. Crane operator replacement

FIGURE M-1. ORGANIZATION CHART FOR OPERATION OF WERDENBERG PLANT to handle the task alone except for some assistance during start-up and shut-down.

The Swiss Federation of Large Boiler Operators provides lectures and training and also issues certificates for general boiler operation. The Widmer & Ernst Company has provided operation and maintenance instructions on each plant component.

Duesseldorf

Table M-4 shows the organization of the 83 persons who constitute the plant staff. The plant operates on a four-shift per day basis with the average work week 43 hours. Normally there are nine workers handling the operation per shift. Job descriptions are published annually and key workers have an organization handbook.

The following principal operators are connected by an intercommunication system:

Crane Operator
Boiler Operator
Shear Operator
Shredder Operator
Tipping Floor (2 locations)

Education and training of Duesseldorf operators is quite structured.

Crane Operator. One year general plant training plus 1 year special training is followed by examination for an operator's license. No special prior education or experience is required.

Boiler Operator. An effort is made to recruit those havinng mechanical training from a 3-year apprenticeship. At this plant he starts as a boiler operator's apprentice for 2 years. There additional training is given 6 hours per week. Then the Technische U Verrein provides a 6-month course, 3 hours per week to prepare for examination for a boiler operator's license.

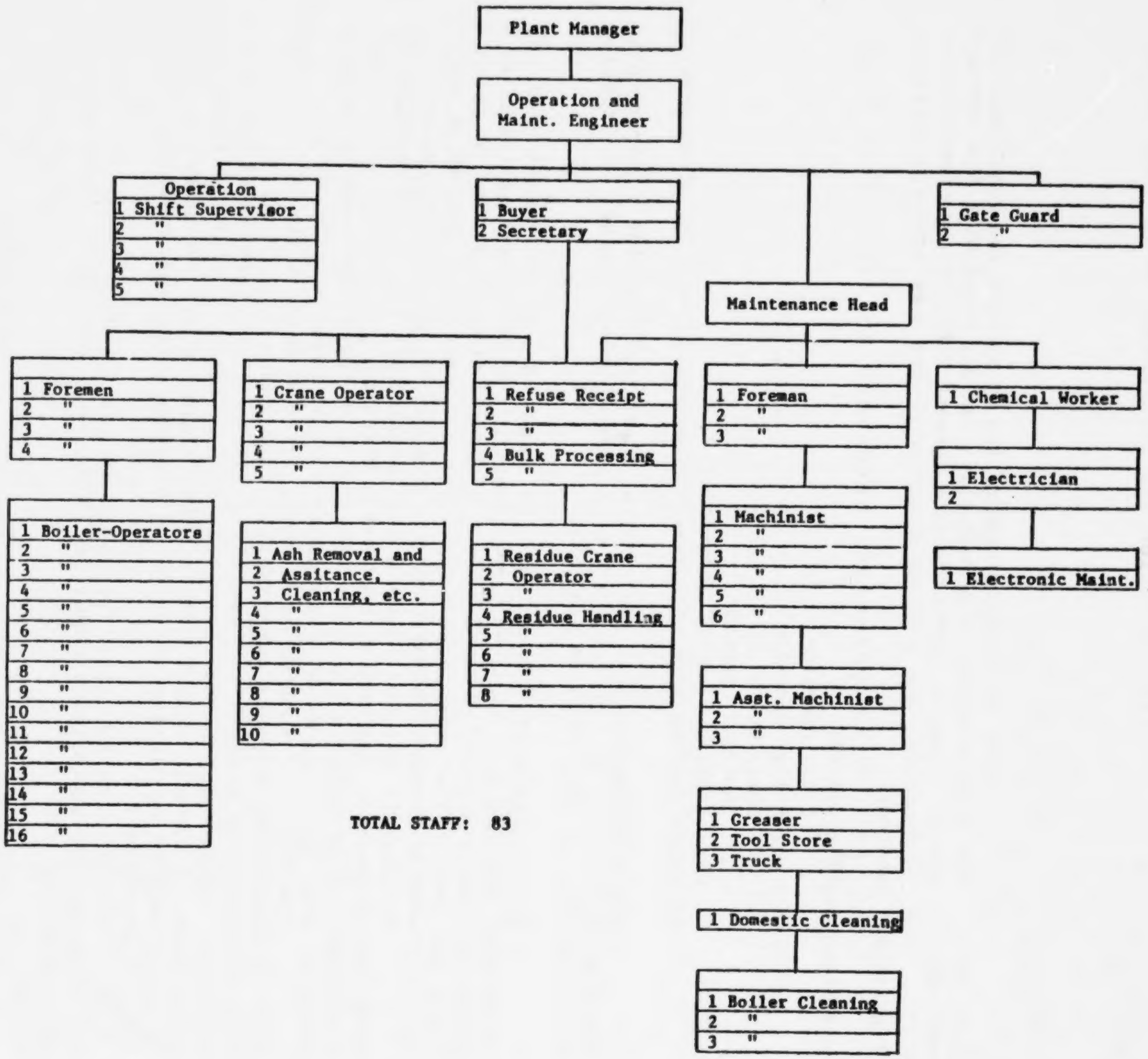
Separately the VGB (Verein des Gosellschaft B _______) (Society for Large Boiler Owners), conducts an on-the-job training program for power plant operators. A prequisite for this training is 6 years experience on boilers, turbines, coal handling, water treatment or similar power-oriented work.

The VGB course total 1500 hours. Without prior training this course must be matched by 8 years experience. Then successful completion of a VGB-administered examination qualifies him as a Kraftwerker (Power Plant Worker). Shift foremen must have this rank. After 1 year of additonal experience he becomes eligible for a 1-year course at the VGB school in Essen, at the successful conclusion of which he becomes a Kraftwerkmeister (Master Power Plant Worker).

Pay scales are developed in negotiation with the workers union. Following are the approximate montly pay rates including 28 to 30 percent for pension and taxes:

	1976 DM	1976 U.S. $
Shift Supervisor	DM 4600	1947
Shift Workekrs	DM 3300	1396
Crane Operator	DM 3300	1396

TABLE M-4. STAFF ORGANIZATION AT STADTWERKE DUESSELDORF WASTE-TO-ENERGY PLANT


Plant Manager
Operation and Maint. Engineer
Operation
1 Shift Supervisor
2 "
3 "
4 "
5 "
1 Buyer
2 Secretary
1 Gate Guard
2 "
Maintenance Head
1 Foremen
2 "
3 "
4 "
1 Boiler-Operators
2 "
3 "
4 "
5 "
6 "
7 "
8 "
9 "
10 "
11 "
12 "
13 "
14 "
15 "
16 "
1 Crane Operator
2 "
3 "
4 "
5 "
1 Ash Removal and
2 Assitance,
3 Cleaning, etc.
4 "
5 "
6 "
7 "
8 "
9 "
10 "
1 Refuse Receipt
2 "
3 "
4 Bulk Processing
5 "
1 Residue Crane
2 Operator
3 "
4 Residue Handling
5 "
6 "
7 "
8 "
1 Foreman
2 "
3 "
1 Machinist
2 "
3 "
4 "
5 "
6 "
1 Asst. Machinist
2 "
3 "
1 Greaser
2 Tool Store
3 Truck
1 Domestic Cleaning
1 Boiler Cleaning
2 "
3 "
1 Chemical Worker
1 Electrician
2
1 Electronic Maint.

TOTAL STAFF: 83

Foremen	DM 3400	1439
Boiler Cleaner	DM 3200	1354
Senior Boiler Operator	DM 3050	1291
Apprentice Boiler Operator	DM 2800	1185
Power Plant Operator	DM 3150	1333
Ash Handler	DM 2600-2800	1100-1185
Electician	DM 2300	973
Shop Foreman	DM 2600	1100

The Boiler Cleaner is paid a relatively high rate because it is difficult, odd-time work.

For the average worker at DM 3000/month, less 30 percent for pension and taxes, his annual take-home pay is 25,000 DM ($10,584 at $0.42/DM).

Wuppertal

Figure M-2 shows the organization chart for the Wuppertal plant.

The plant operates 24 hours per day three shifts, 7 days per week. The individual work week is 40 hours.

There are 100 employees. The average shift workers are paid DM 25,000/yr including fringe benefits ($11,000/yr at DM 2.27/$). The total annual payroll is 37,000,000 DM ($16,250,0000.

The commercial managerr and supervisor have additonal off-site duties with the Wuppertal City Administration. Mr. Masanek is also responsible for Wuppertal's Transportation Department. Mr. Hilkes, the Commercial Supervisor, only works for the plant 60 percent of the time.

Data processing is done on a Niksdorf System 8000 located at the plant.

Krefeld

The plant operates 24 hours per day, three shifts, 7 days per week. The individual work week is 40 hours.

Paris: Issy

Electricitie de France (E.D.F.) is France's national electric company and is owned by the Federal government. In 1946, E.D.F. established the Service du Traitment Industriel des Residus Urbans (T.I.R.U.) for the purpose of operating refuse-fired steam generators.

Products from the T.I.R.U. plants were to be:

- Electricitysold to T.I.R.U.'s sister company, C.I.M.E., which is E.D.F.'s electricity distribution subsidiary.
- Steam sold to a separate organization, Compagnie Parisimne de Chauffage Urbain (C.P.C.U.).

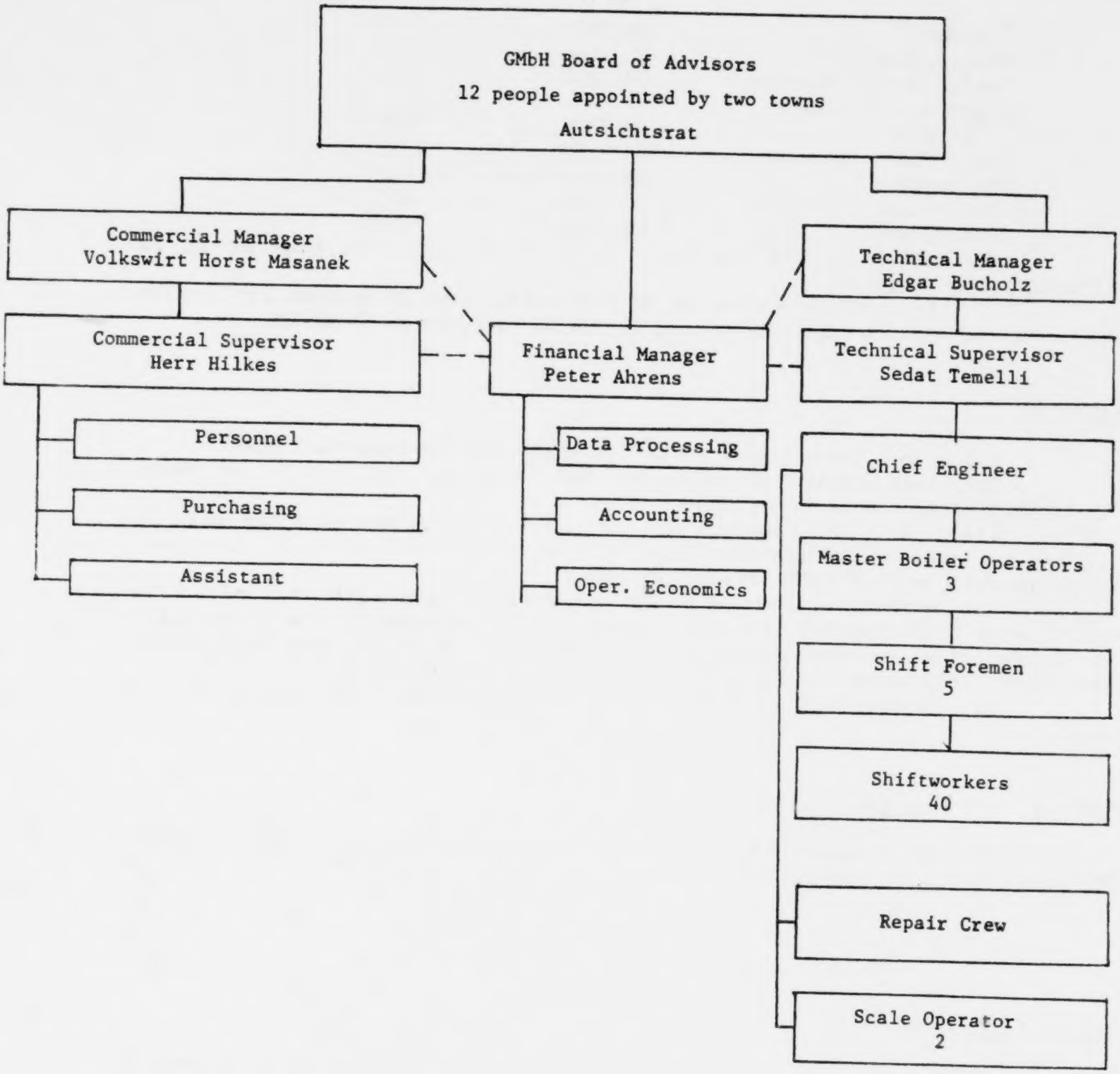

GMbH Board of Advisors
12 people appointed by two towns
Autsichtsrat
Commercial Manager
Volkswirt Horst Masanek
Technical Manager
Edgar Bucholz
Commercial Supervisor
Herr Hilkes
Financial Manager
Peter Ahrens
Technical Supervisor
Sedat Temelli
Personnel
Purchasing
Assistant
Data Processing
Accounting
Oper. Economics
Chief Engineer
Master Boiler Operators
3
Shift Foremen
5
Shiftworkers
40
Repair Crew
Scale Operator
2

FIGURE M-2. WUPPERTAL ORGANIZATION CHART

It is important to understand how all of these large organizations relate. With that understanding, the personnel and management situation of T.I.R.U. and it's Issy plant can be placed in its proper perspective. As indicated earlier in the report, the City of Paris has a parallel contractual relation as do 54 other metropolitan communities.

The T.I.R.U. organization chart is shown in Figure M-3. Mr. Defeche is the Chief of the Services T.I.R.U. The plant managers report to him as does Mr. Jullien, Director of the Technical Department. The other positions are shown includinng Mr. Finet, head of the Pollution Control Section.

Hamburg: Stellinger-Moor

The organization chart shown in Figure M-4 describes the organization structure of Stellinger-Moor. Herrs, Opperman, Rossi, Grosstueck, and VonBorck have city-wide responsibility and their offices are located near Borsigsrtrasse. Mr. Arndt has about 70 people on the payroll within plant gates. Many employees are used for vacations and sickness replacements as shown below:

	Operations	Maintenance and Administrative	Total
Sickness	11	4	15
Vacation	5	6	11
			26

Thus, on a typical 24-hour day, 26 people wwill be away from work for sickness or vacation and 44 will be actively working.

Employees are remunerated by a basic wage. This is supplemented by a bonus that is a function of steam and electrical production.

Zurich: Hagenholz

Figure M-5 displays the city of Zurich's organization. The Hagenholz plant itself is part of the Abfuhrwesen (Waste Disposal Organization) which reports to Gesundheits - und Wirtschaflsamt (Health and Cleansing Department). Note that the Abfhrwesen Heizamt (city's heating organization) and the Elekrizitatswerk (electrical works) are each in different departments. This makes more impressive the attitude of Max Baltensperger, Chief of the Waste Disposal Organization, that the Hagenholz RFSG is primarily an energy facility and secondarily a waste disposal facility.

The waste collection, Hagenholz, Josefstrasse, and rendering plant relationships are shown in Abfuhrwesen organization chart: Figure M-6. The activities above the dash line are performed at City Hall.

Compared to other European RFSG plants, the plant level organization chart is less precise. There are no shift specialists. Each man gets to do all the jobs around the plant. The philosophy is that the men should take more interest in the overall plant operation. Changing assignments also tend to inhibit formation of cliques and selfish attitudes.

Each of the 39 men work a 44-hour week. There are four operators per shift as follows: shift foreman, crane operator, maintenance man, and control

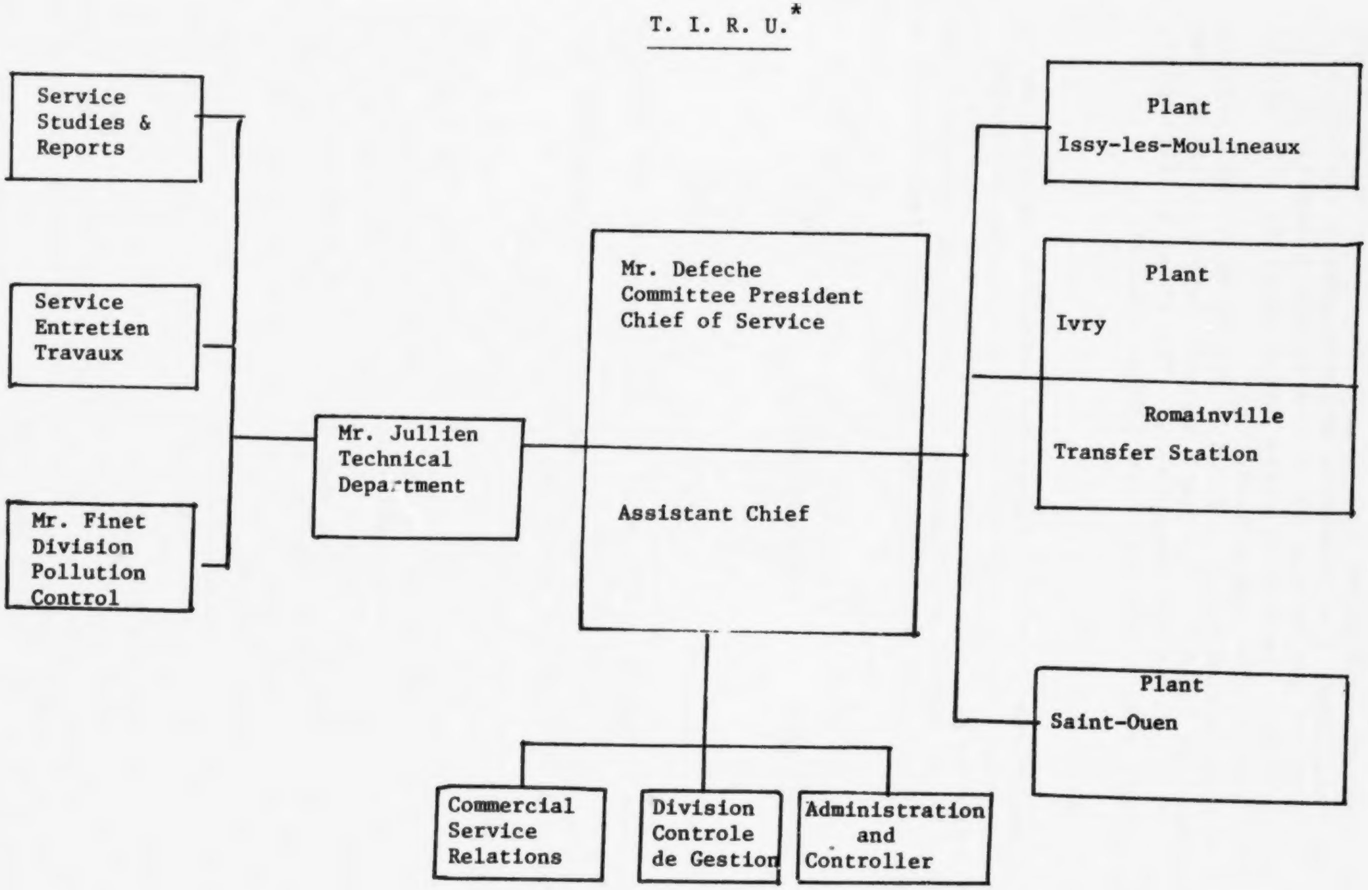

T. I. R. U.*
Service Studies & Reports
Service Entretien Travaux
Mr. Finet Division Pollution Control
Mr. Jullien Technical Department
Mr. Defeche Committee President Chief of Service
Assistant Chief
Commercial Service Relations
Division Controle de Gestion
Administration and Controller
Plant Issy-les-Moulineaux
Plant Ivry
Romainville Transfer Station
Plant Saint-Ouen

FIGURE M-3. ORGANIZATION CHART OF TIRU IN PARIS

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*Service du Traitment Industriel des Residus Urbans
(Service for the Industrial Treatment of Urban Waste)

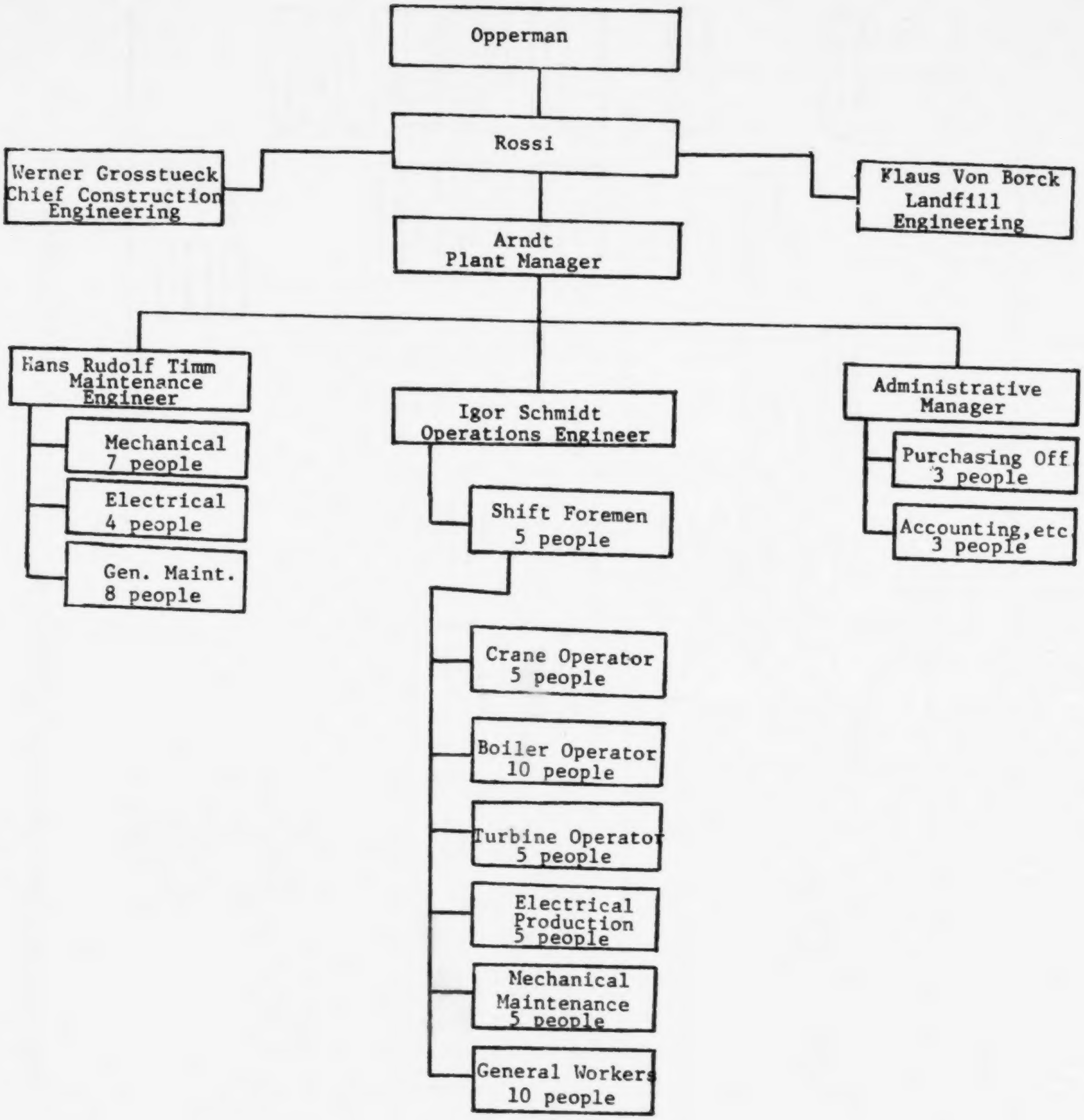
Opperman
Rossi
Werner Grosstueck Chief Construction Engineering
Klaus Von Borck Landfill Engineering
Arndt Plant Manager
Hans Rudolf Timm Maintenance Engineer
Mechanical 7 people
Electrical 4 people
Gen. Maint. 8 people
Igor Schmidt Operations Engineer
Shift Foremen 5 people
Crane Operator 5 people
Boiler Operator 10 people
Turbine Operator 5 people
Electrical Production 5 people
Mechanical Maintenance 5 people
General Workers 10 people
Administrative Manager
Purchasing Off. 3 people
Accounting, etc. 3 people

FIGURE M-4. ORGANIZATION CHART FOR HAMBURG: STELLINGER-MOOR

Reproduced from best available copy.

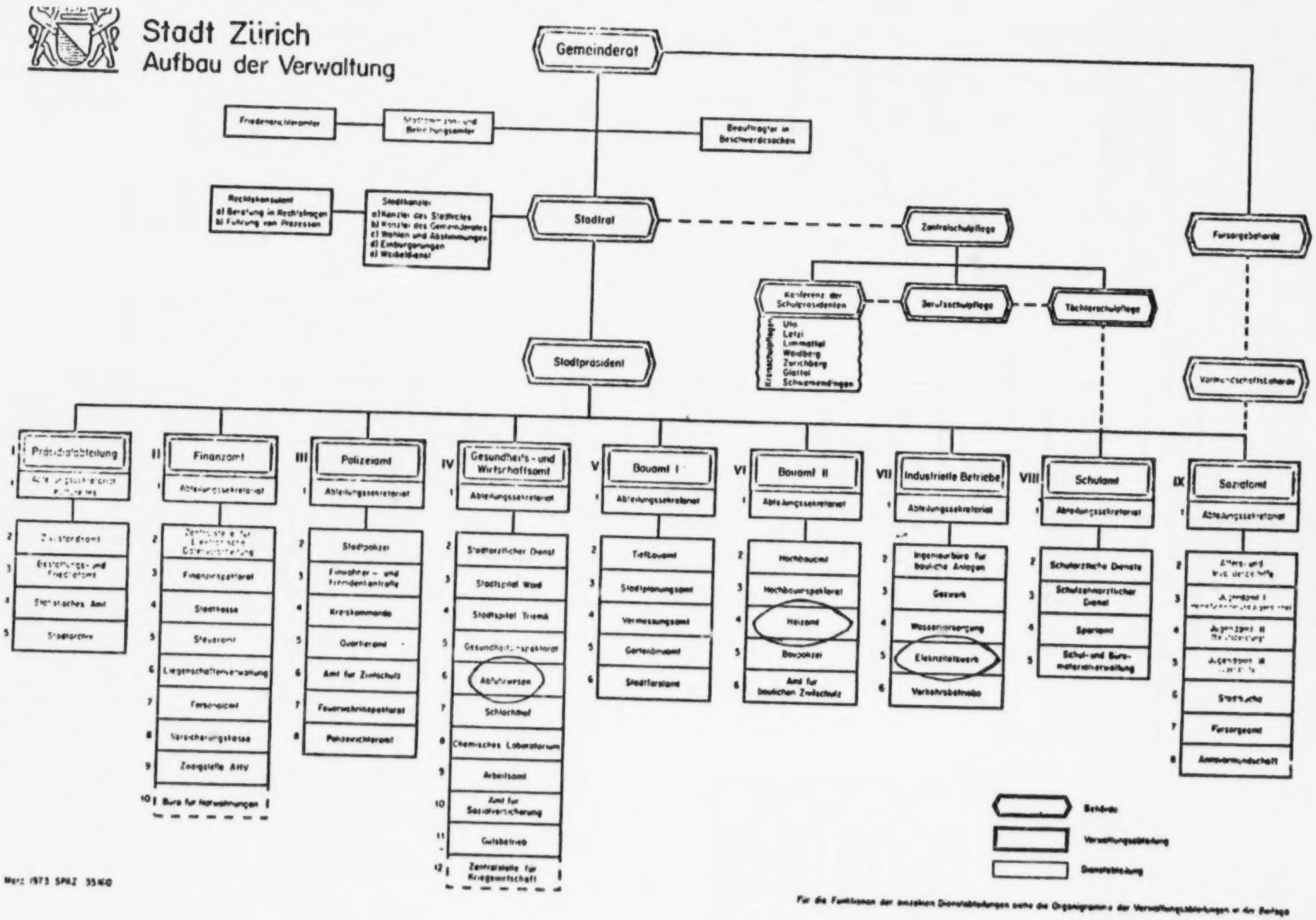
Stadt Zürich
Aufbau der Verwaltung
Gemeinderat
Friedensrichterämter
Stadtammann- und Betreibungsämter
Beauftragter in Beschwerdesachen
Rechtskonsulent
a) Beratung in Rechtsfragen
b) Führung von Prozessen
Stadtkanzlei
a) Kanzlei des Stadtrates
b) Kanzlei des Gemeinderates
c) Wahlen und Abstimmungen
d) Einbürgerungen
e) Weibeldienst
Stadtrat
Zentralschulpflege
Konferenz der Schulpräsidenten
Kreisschulpflegen
Uto
Letzi
Limmattal
Waidberg
Zürichberg
Glattal
Schwamendingen
Berufsschulpflege
Töchterschulpflege
Fürsorgebehörde
Vormundschaftsbehörde
Stadtpräsident
I
Präsidialabteilung
1
2 Zivilstandsamt
3 Bestattungs- und Friedhofamt
4 Statistisches Amt
5 Stadtarchiv
II
Finanzamt
1 Abteilungssekretariat
2 Zentralstelle für Elektronische Datenverarbeitung
3 Finanzinspektorat
4 Stadtkasse
5 Steueramt
6 Liegenschaftenverwaltung
7 Personalamt
8 Versicherungskasse
9 Zweigstelle AHV
10 Büro für Notwohnungen
III
Polizeiamt
1 Abteilungssekretariat
2 Stadtpolizei
3 Einwohner- und Fremdenkontrolle
4 Kreiskommando
5 Quartieramt
6 Amt für Zivilschutz
7 Feuerwehrinspektorat
8 Polizeirichteramt
IV
Gesundheits- und Wirtschaftsamt
1 Abteilungssekretariat
2 Stadtärztlicher Dienst
3 Stadtspital Waid
4 Stadtspital Triemli
5 Gesundheitsinspektorat
6 Abfuhrwesen
7 Schlachthof
8 Chemisches Laboratorium
9 Arbeitsamt
10 Amt für Sozialversicherung
11 Gutsbetrieb
12 Zentralstelle für Kriegswirtschaft
V
Bauamt I
1 Abteilungssekretariat
2 Tiefbauamt
3 Stadtplanungsamt
4 Vermessungsamt
5 Gartenbauamt
6 Stadtforstamt
VI
Bauamt II
1 Abteilungssekretariat
2 Hochbauamt
3 Hochbauinspektorat
4 Heizamt
5 Baupolizei
6 Amt für baulichen Zivilschutz
VII
Industrielle Betriebe
1 Abteilungssekretariat
2 Ingenieurbüro für bauliche Anlagen
3 Gaswerk
4 Wasserversorgung
5 Elektrizitätswerk
6 Verkehrsbetriebe
VIII
Schulamt
1 Abteilungssekretariat
2 Schulärztliche Dienste
3 Schulzahnärztlicher Dienst
4 Sportamt
5 Schul- und Büromaterialverwaltung
IX
Sozialamt
1 Abteilungssekretariat
2 Alters- und Invalidenbeihilfe
3 Jugendamt I
4 Jugendamt II
5 Jugendamt III
6 Stadtküche
7 Fürsorgeamt
8 Amtsvormundschaft
Behörde
Verwaltungsabteilung
Dienstabteilung
März 1973 SPAZ 35160
Für die Funktionen der einzelnen Dienstabteilungen siehe die Organigramme der Verwaltungsabteilungen in der Beilage

FIGURE M-5. ORGANIZATION CHART FOR MUNICIPAL FUNCTIONS IN THE CITY OF ZURICH: SWITZERLAND

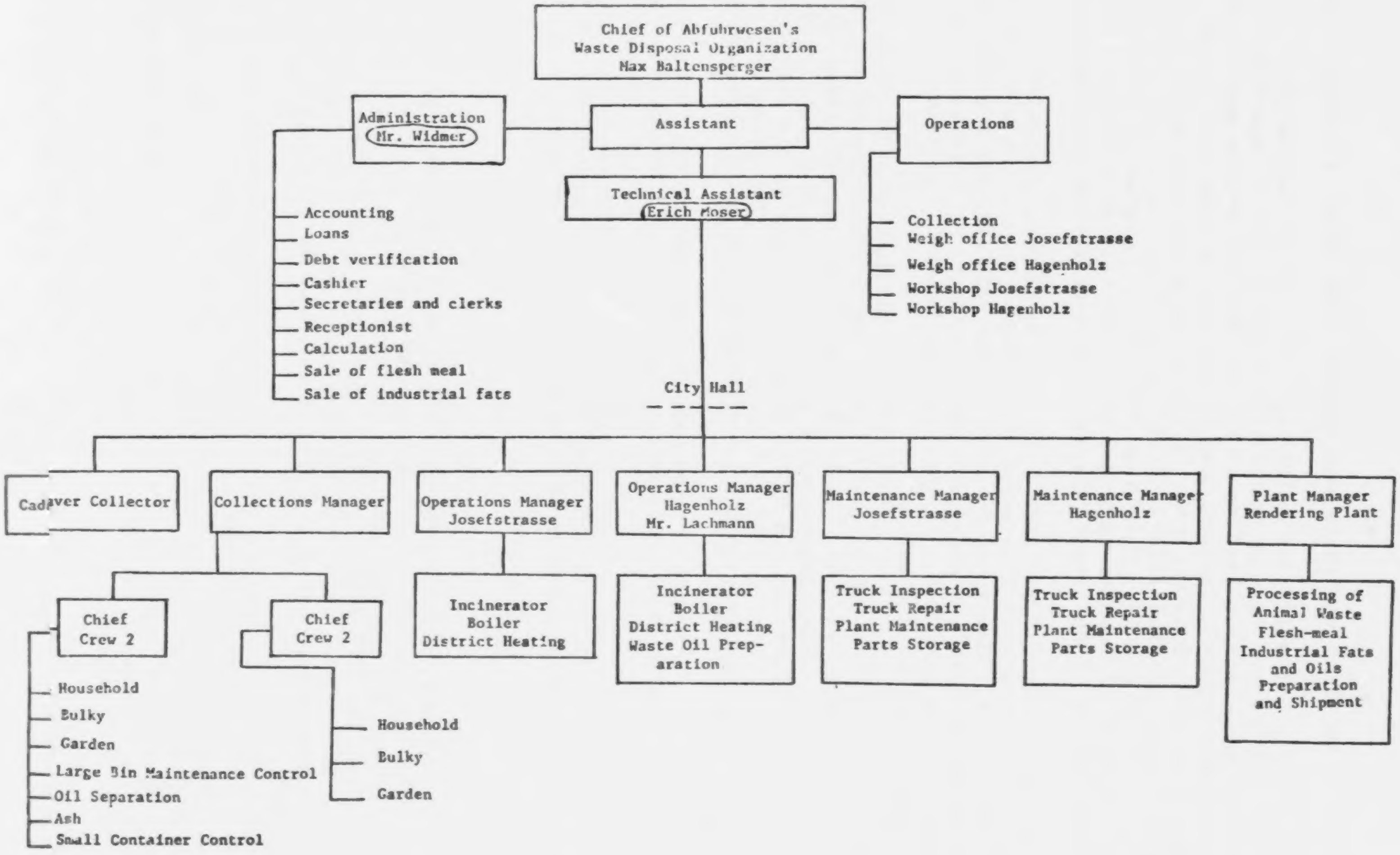
Chief of Abfuhrwesen's
Waste Disposal Organization
Max Baltensperger
Administration
Mr. Widmer
Assistant
Operations
Technical Assistant
Erich Moser
Accounting
Loans
Debt verification
Cashier
Secretaries and clerks
Receptionist
Calculation
Sale of flesh meal
Sale of industrial fats
Collection
Weigh office Josefstrasse
Weigh office Hagenholz
Workshop Josefstrasse
Workshop Hagenholz
City Hall
Cadaver Collector
Collections Manager
Operations Manager
Josefstrasse
Operations Manager
Hagenholz
Mr. Lachmann
Maintenance Manager
Josefstrasse
Maintenance Manager
Hagenholz
Plant Manager
Rendering Plant
Chief
Crew 2
Chief
Crew 2
Incinerator
Boiler
District Heating
Incinerator
Boiler
District Heating
Waste Oil Preparation
Truck Inspection
Truck Repair
Plant Maintenance
Parts Storage
Truck Inspection
Truck Repair
Plant Maintenance
Parts Storage
Processing of
Animal Waste
Flesh-meal
Industrial Fats
and Oils
Preparation
and Shipment
Household
Bulky
Garden
Large Bin Maintenance Control
Oil Separation
Ash
Small Container Control
Household
Bulky
Garden

FIGURE M-6. ORGANIZATION CHART FOR WASTE COLLECTION AND DISPOSAL IN ZURICH, SWITZERLAND room operator. Services contracts with outside firms permit a limited staff size.

While the plant staff has walkie talkies, they are seldom used. The crane operators and the control room operators frequently talk by telephone.

Switzerland, being a landlocked nation, does not have as many former seamen running their boilers. Instead, some of the people come from industry such as Brown Boveri, Sulzer, etc. Often a young man will start as an apprentice machinist or pipefitter. Training is primarily on the job as compared with the rigorous schooling/experiency program in Germany. Accordingly, promotion is based on merit and actual contribution to the plant operations and not based on formal progression through a schooling/experience program.

The total number of personnel (collection, disposal, administration, rendering plant, etc.) since 1911 is shown Figure M-7. Notice the 100 person drop from 1970 to 1976. When asked for reasons, the main response was that the new attitude specified that all employees should be busy on necessary jobs. Featherbedding is not permitted. If the person performing a job is not active enough, the position may be eliminated.

Plant staff stated that the change from garbage cans to paper and plastic bags greatly reduced the manpower requirements for collectors. The third reason for keeping manpower levels low, costs low, and efficiency high, is the bonus. In 1976, management shared SF 2,737 while the plant people shared SF 17,617. A fourth reason is the 50 percent of the people are in the local union. But these are primarily the older workers. The young are not joining in such large numbers and the labor union is thus not as effective in adding workers.

At one point, a comparison was made between Hamburg: Stellinger-Moor and Zurich:Hagenholz. Both plants are operated by municipal governments. At Hamburg, the primary objective is "clean disposal of waste". The main difference was that Stellinger-Moor is casually operated as a well-run municipal department with an influential labor union. Hagenholz however is lean and efficient and is operated as if it were private enterprise.

The Hague

The plant was built by the city and is under the overall management of the Director of Utilities who also oversees the operation of the adjacent 200 Mw power plant and gas and district heating facility. That combined facility has a staff of 1500 workers. Major repairs of the refuse plant are handled by the maintenance staff from the main power plant. Mr. Postma, plant manager, gives a report each day on his plant's operation to the manager of the utilities plant.

The plant staff numbers 54, including the manager and assistant manager. There are 33 operating personnel divided over four shifts as follows:

- 4 Mechanics
- 4 Machinist-Turbines
- 4 Boiler Operators
- 4 Crane Operators
- 8 Relief Mechanics
- 4 Laborers
- 5 Reserve Shiftworkers
- 2 Slag Crane Operators
- 2 Electricians
- 2 Meter and Control Technicians
- 3 Pipefitters
- 2 Operators for Hospital Refuse Burner
- 1 Janitor 7 Outside Maintenance Staff

Amount of Staff from 1911

Abfuhrwesen

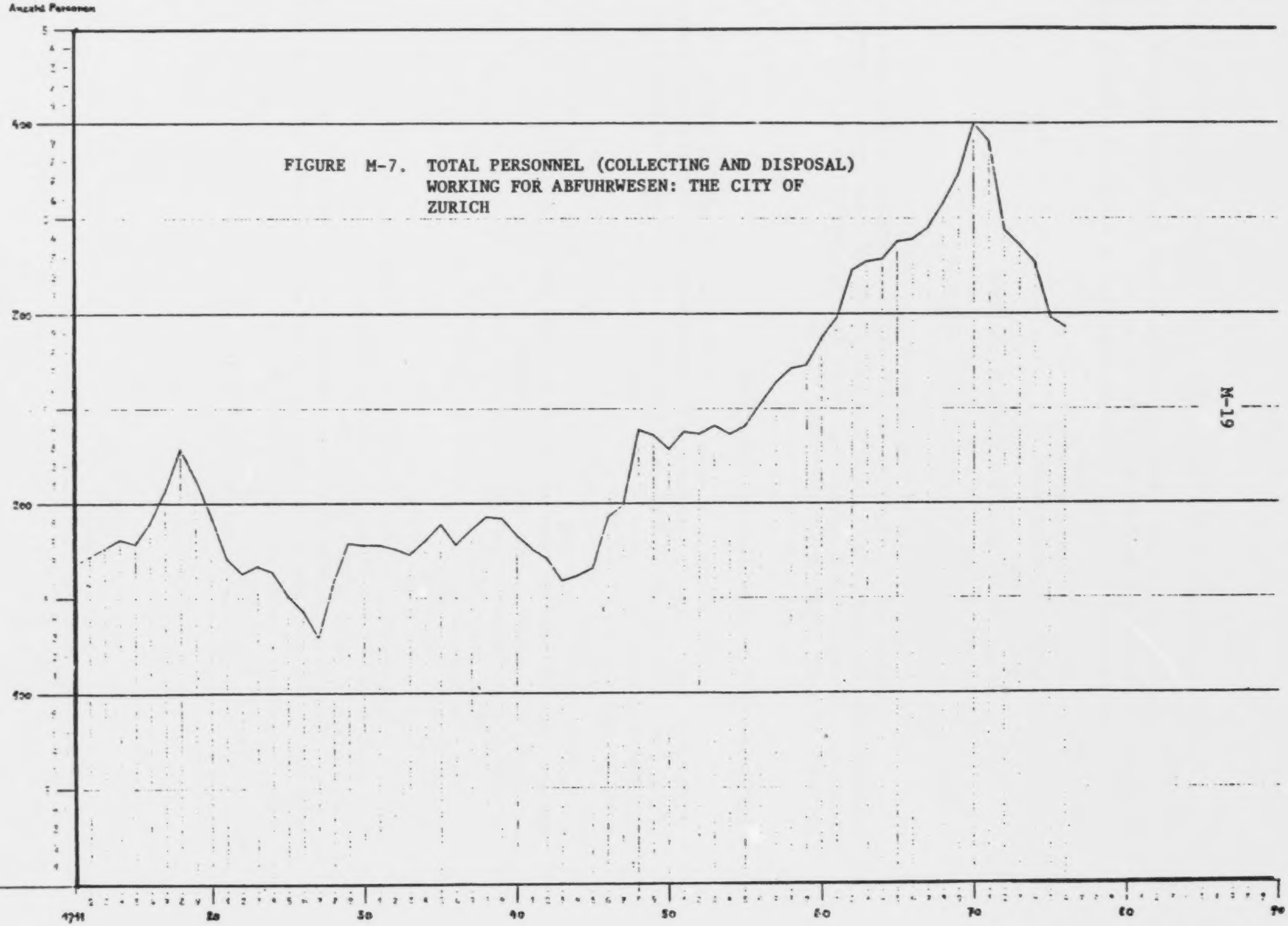

FIGURE M-7. TOTAL PERSONNEL (COLLECTING AND DISPOSAL) WORKING FOR ABFUHRWESEN: THE CITY OF ZURICH

The work week is 40 hours. All jobs are described in available plant records.

The key staff all have marine experience: the chief engineer - 10 to 15 years, the assistant engineers - 8 to 10 years.

Attainment of a marine chief engineer's status in the Netherlands requires:

12 years through high school
2 years marine school
1 year at sea
3/4 year training as third class engineer
2 years at sea
1 year training as second class engineer
3 years at sea
1-1/2 to 2 years training as chief engineer.

Although marine training is obviously not crucial to the operation of a waste-burning power plant, this type and extent of experience is essential in preparing the principal operating staff for successfully coping with the problems of waste burning and producing energy.

Dieppe (Similar to Deauville 50 Miles Away)

M. Jeane Fossey, Dieppe Plant Manager, is an employee of INOR S. A. (Societe de construction d'usines, pour l'incineration des ordures menageres) (Firm for Construction of Facilities for the Incineration of Community Refuse), the Paris industrial organization which built and, along with Thermical, operates the plant for the city of Dieppe.

M. Fossey had experience in the merchant marine. His assistant manager has pressure vessel experience and can also serve as a mechanic and welder. They direct the work of 14 other staff as follows:

- 3 control room and crane operators*
- 3 furnaces room operators*
- 1 electrician*
- 1 scale operator
- 1 mechanic*
- 1 assistant mechanic
- 2 aides (for cleaning and housekeeping)
- 1 driver (loads and hauls clinker)
- 3 furnace room operators.

Originally, the work week was 48 hours. Now it is 42. There are usually six men on a shift. French law requires that wherever high pressure steam is used, at least two men must be on duty.

The total annual staff cost in 1976 was about 850,000 FFr ($178,500 @ 4.76 FFr/$). To this must be added social benefit costs which total about 50 to 55 percent.

---

*Can also serve as shift foreman.

Gothenburg

Mr. Bengt Rundqwist, the Plant Director, reports to the Board of GRAAB. He prepares the agenda for the Board's working committee which meets about twice per month. His total staff is 48. There are four shifts, four workers per shift: foreman, crane operator, furnace man, and control room operator. Formerly, the work week for shift workers was 40 hours, but now it is 32.3 hours because it is demanding work. The maintenance staff works a 40-hour week.

The salary of the shift foreman is 5,600 to 5,800 S.Kr./mo ($1,120 to $1,160), including social benefits. The crane operator earns 4,800 S.Kr./mo. Workers receive free working clothes, special shoes once per year, subsidized cafeteria service and coffee, and use of the sports club equipment, maintenance of which costs 3,000 to 4,000 S.Kr./yr. Free classes and training are provided. The plant participates in a cooperative education program.

Many workers are recruited from the navy and merchant marine and nearby refineries. All workers have had 9 years normal schooling. A boiler operator must have 1 year of special schooling plus 40 weeks of practice.

The workers' union has the right to review all questions that affect workers before they go to the Board for consideration. If the planned-for eventual fourth unit is considered, it must have union approval.

Figure M-8 shows the spacious control room with comfortable rest center at rear left.

Uppsala

Chief Engineer, Hans Nyman, directs the overall plant through his staff, Han Nordstrom, plant Engineer, and Karl-Eric Berg, Works Engineer, and his assistant works engineer.

The plant does not now operate on weekends. The work week is now 38.5 hours with 170 hours per month. Every ninth week, each worker works for shorter days. The regulation 4-week vacation will be extended to 5 weeks in 1978.

On the three daily shifts, there are five workers as follows:

- Crane Operator
- Slag and Residue Handler
- Boiler-Furnace Operator
- Scale Operator (day shift only)
- Mechanic (and on call for scale).

There is a possibility that more refuse will be coming from neighboring cities. To handle the extra volume, 7-day operation will be planned for which it is expected nine additional workers will be needed, three for each of three weekend shifts.

Horsens

Erling Peterson is Director of Solid Waste Management and Wastewater Treatment for the Horsens area. Actual operation of both plants is managed by

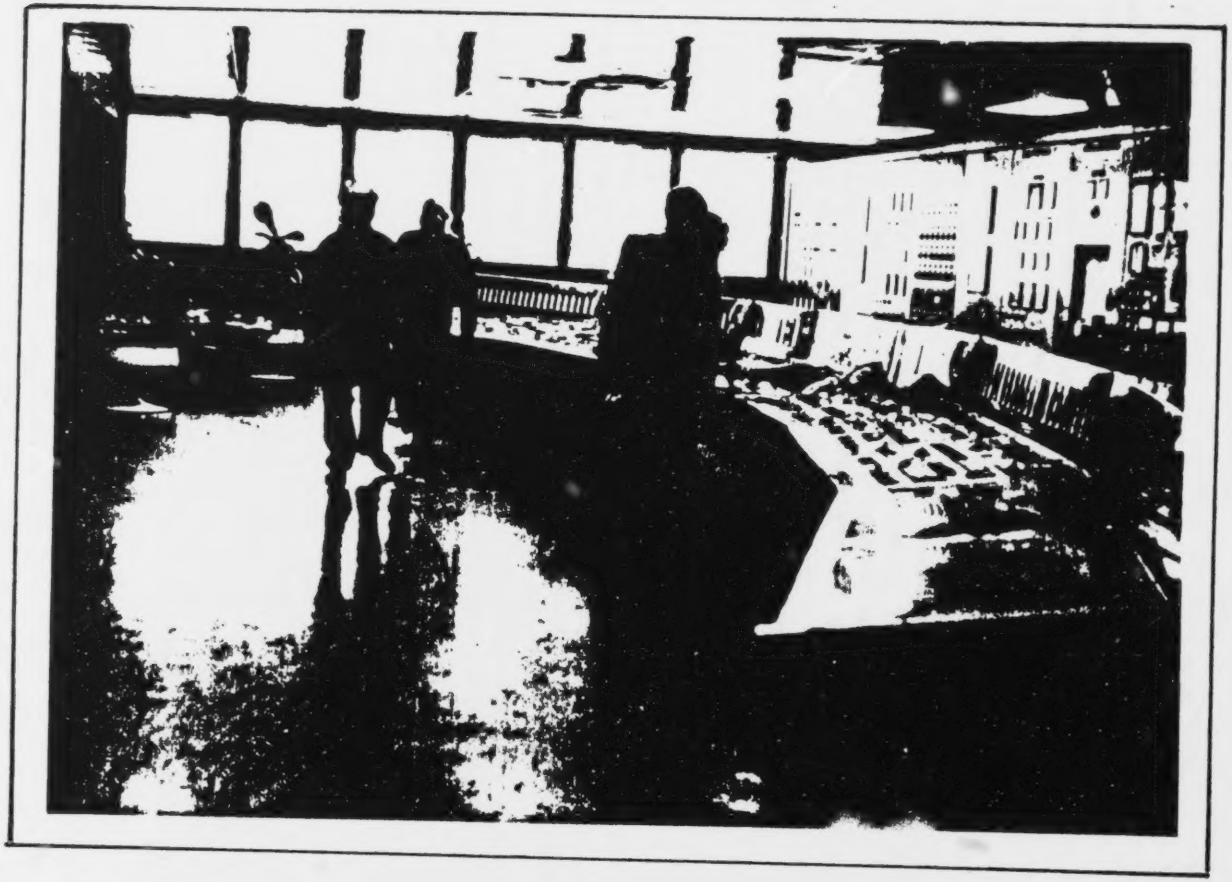

FIGURE M-8. CONTROL ROOM AT SAVENAS PLANT. THE FOLIAGE PLANTS AT LEFT DECORATE THE COFFEE AND REST AREA. (Battelle Photograph)

Finn Larsen whose office is in the town hall.

Copenhagen: Amager

The Amager operations are managed by representives from the five communes listed in Figure M-9. Note that 18 people attend the annual general meeting (community stockholders meeting).

More frequent meetings are held with the management committee of six representatives; a chairman, and the borgomiester from each commune.

Finally, the day-to-day administrative director is the focal point for the communities with the plant personnel.

Amager's personnel structure is based on five shifts: early mornings, days, nights, weekends, and replacements. Each shift has four key men -- the supervisor, boiler tender, furnace tender, and crane operator -- for a total of 20 operating men.

Another 23 men are utilized in maintenance, repairs, and cleaning. Two men are used at the scale house and two are used on the tipping floor.

The administration personnel number six people: director, operating manager, office manager, two office employees, and a canteen lady.

Realizing that the plant runs 24 hours per day, 365 days per year, many of the above personnel are used as vacation, holiday, and sick replacements. Considering this, the total plant staff numbers 53 employees.

Copenhagen: West

The 12 communities have two large organizations that are responsible for West general operation and important policies. Figure M-10 shows the many representatives to the General Meeting held once per year.

The actual managing board is comprised of one of these persons per community. Thus the board has twelve community representatives plus the plant manager.

About 56 people work at the plant on its three shifts, 7 days per week. Details of the job title, shift, hours/day, days/week, and duties are shown below:

- Adminstration - One shift = 8 hours/day, 5 days/week
  - One managing director (part-time)
  - One technical consultant
  - One plant manager
- Bookkeeping - One shift = 8 hours/day
  - One manager
  - One bookkeeper/cashier
  - One clerk (telephone attendant/typewriting)
  - One clerk (part-time) (typewriting)
  - One office boy
- Cleaning - One shift = 8 hours/day, 7 days/week
  - Two women for cleaning offices and canteen
- Refuse cranes - Three shifts = 24 hours/day, 7 days/week
  - Three crane operators
  - Two reserve operators for holidays, vacations, and sickness.

1975-76

COMMUNES

Dragør kommune
Frederiksberg kommune
Hvidovre kommune
Københavns kommune
Tårnby kommune

REPRESENTATIVES TO THE ANNUAL COMMUNITY SHAREHOLDERS MEETING

Borgmester Alb. Svendsen
Viceborgmester Chr. Lauritz-Jensen
Landsformand Arne Ginge
Borgmester Svend Aagesen
Kommunalbestyrelsesmedlem Jens Kristensen
Kommunalbestyrelsesmedlem Alf Christensen
Borgerrepræsentant Gunnar Ulbæk
Borgmester Lilly Helveg Petersen
Borgmester A. Wassard
Forretningsfører Andreas E. Hansen
Overborgmester Egon Weidekamp
Overlærer Kit Falbe Hansen
Skoleinspektør Niels Jørn Hougård
Typograf Kurt Kristensen
Havnemester Elhardt Madsen
Borgmester Tork. Feldvoss
Generalauditør Jens Harpøth
Journalist Marcelino Jensen

MANAGEMENT COMMITTEE

Borgerrepræsentant Gunnar Ulbæk (formand)
Borgmester Lilly Helveg Petersen
Viceborgmester Chr. Lauritz-Jensen
Borgmester Tork. Feldvoss
Borgmester Svend Aagesen
Borgmester Alb. Svendsen

ADMINISTRATIVE DIRECTOR

Willy Brauer (administrerende direktør)

FIGURE M-9. MANAGEMENT STRUCTURE OF COPENHAGEN: AMAGER

Members of West General Assembly and Board of Directors Chosen for the Period of April 1, 1974 to March 31, 1978

BALLERUP KOMMUNE

Borgmester, cand. jur. Kaj H. Burchardt,
formand for bestyrelsen
Chauffør Helge Hansen
Postvagtmester Skjold Jacobsen
TV-tekniker Arne Maischnack
Skatterådsformand Gudrun Petersen
Fabrikant Knud Pedersen
Typograf Knud Ø. Rasmussen

BIRKERØD KOMMUNE

Trafikkontrollør Poul E. Frederiksen
Byrådsmedlem Birthe Larsen
Major H. Søndergaard-Nielsen
Byrådsmedlem Hans Rasmussen,
bestyrelsesmedlem

FARUM KOMMUNE

Sognepræst T. Gudmand-Høyer
Politiassistent Villy Hansen, best.medlem
Adjunkt Eva Møller

GENTOFTE KOMMUNE

Skoleinspektør Erik Gruno
Viceskattedirektør Bent Kristensen
Fuldmægtig, cand. jur. Birthe Philip
Kommunalbestyrelsesmedlem Inge Skafte
Husholdningskonsulent Ellis Tardini
Vicedirektør Steen Vedel, best.medlem
Adm. direktør Bjarne Lehmann Weng

GLADSAXE KOMMUNE

Postbud Kaj Bruhn Andersen
Redaktør Ole Andersen
Husholdningslærer Kirsten Beck
Lærer Lauge Dalgård
Skolebetjent Tage Hansen, best.medlem
Fabrikant Otto Marcussen
Lærer Lars Nielsen

GLOSTRUP KOMMUNE

Forretningsfører Børge Jansbøl
Direktør Leo Lollike
Borgmester Martin Nielsen,
bestyrelsens næstformand
Bygningssnedker Bent Wolff

HERLEV KOMMUNE

Borgmester Ib Juul
Ingeniør Erik Breith
Afdelingsgeolog Henning Kristiansen,
bestyrelsesmedlem
Kommunalbestyrelsesmedlem Hans Ohlsen

KØBENHAVNS KOMMUNE

Forretningsfører Andreas E. Hansen
Kontorchef H. Thustrup Hansen
Overlærer Niels Jørgen Hougaard
Typograf Kurt Kristensen
Borgmester Lilly Helveg Petersen
Borgerrepræsentant Gunnar Ulbæk,
bestyrelsesmedlem
Overborgmester Egon Weidekamp

LEDØJE-SMØRUM KOMMUNE

Borgmester Eigil Paulsen, best.medlem
Salgschef Ib Petersen

LYNGBY-TAARBÆK KOMMUNE

Ekspeditionssekretær Carlo Hansen
Borgmester Ole Harkjær
Typograf Vivi Henriksen
Fagforeningsformand Birgil Cort Jensen
Civilingeniør Palle Løvdal
Direktør Kaj Kramer Mikkelsen,
bestyrelsesmedlem
Cand. polit. Inge Schjødt

RØDOVRE KOMMUNE

Direktør Chr. Helmer Jørgensen
Typograf Ebbe Kristensen
Grosserer Tage Nielsen
Advokat Bent Osborg, best.medlem
Lagerarbejder Hans Rasmussen

VÆRLØSE KOMMUNE

Kommunalbestyrelsesmedlem
Nette Holmboe Bang
Kommunalbestyrelsesmedlem
Elo Christensen
Borgmester E. Ellgaard, best.medlem

FIGURE M-10. ANNUAL GENERAL MEETING PARTICIPANTS

One of the operators will always be free as each operator has 8 extra free hours (1 day) for each 40 hours work. The other reserve operator works half a day with the reserve crane cleaning the silo entrance ports and half a day for cleaning and removing the clinkers in the ash silo.
  - One reserve operator (day time) for lubricating and cleaning. (This reserve will be in full work as soon as more than two crane operators are free and on sick leave.)
- Ash cranes - One shift = 8 hours/day, 5 days/week
  - (One reserve operator from the refuse crane will help clean the silo in the afternoon.) The crane operator is free on Saturdays and Sundays.
- Control Room, Furnaces, and Boilers - Three shifts = 24 hours/day, 7 days/week
  - Three foremen. Their duties are to sample the water for the boilers, start for testing the emergency generator, control the water on the air conditioning system, control level of hot water tank and changing (repair) of instruments.
  - Three boiler attendants. These attendants take care of the boiler and help the foremen with their duties.
  - Three furnace attendents. These attendants watch the furnace equipment, clean the boilers and take care of general cleaning of the plant.
  - Three reserve foremen
  - Three reserve boiler attendants
  - Three reserve furnace attendants. The reserve crew is used for sick leave, vacation, and free days, and when not in full use, help the duty crew with their duties.
- Workshop - One shift = 8 hours/day, 5 days/week
  - One foreman
  - Two electricians
  - six artisans
- Cleaning - One shift = 8 hours/day, 5 day/week
  - Three unskilled workers. These workers help in the workshop and the plant in general and take care of the general cleaning.
- Weighing Bridge - Two shifts = 16 hours/day
  - Three attendants. There first attendant works from 6:00 a.m. to 12:30 p.m. The second attendant works from 12:30 a.m. to 9:00 p.m. The third attendant works from 8:00 a.m. to 4:00 p.m. The third attendant will be on the first or the second shift in case of sick leave or vacations. Every third weekend one of the attendants is on duty, Saturdays from 6:00 a.m. to 3:00 p.m. and Sunday from 6:00 a.m. to 3:00 p.m.
- Refuse Reception Hall - One shift = 8 hours/day, 5 days/week
  - One unskilled worker. Directs the traffic in the hall, taking care that no large pieces of iron or similar are discharged into the refuse silo.
- Refuse Crusher - One shift = 8 hours/day, 5 days/week
  - One unskilled worker. Operates the crusher.
- Ash Diposal
  - For this purpose, the plant contracts a lorry with driver for transport of the ashes to a close-by disposal area.

Education and Experience

When staffing the plant, education and experience are desired as listed below:

- Managing Director
  - The title should explain the qualifications required to manage the plant
  - The managing director is only employed part-time as the plant has a technical consultant who takes care of the daily problems.
- Technical Consultant
  - Mechanical Engineer degree or the equivalent
- Bookkeepers
  - The personnel is defined by the degrees indicated and positions held
- Crane Operators
  - Artisan or unskilled worker trained at the plant
- Foreman
  - Engineer (marit.) with electrical installation
- Boiler Attendant
  - With official certificate as boiler attendant
- Furnace Attendance
  - Artisan or unskilled worker trained at the plant
- Electrician
  - Qualified as electrician
- Weighing Bridge Attendant
  - Clerk training as the jobs require checking of accounts and other administration work.

APPENDIX

REFERENCES

FOR

SPEC REPTS 1 & 2

(These references are also listed
at the point of use in the
individual chapters.
They are assembled again
here for easy access.)

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LIST OF PERSONS CONTACTED

Persons and Titles

The Battelle investigators are please to acknowledge the very competent, energetic and generous assistance which we received from the following.

Werdenberg - Liechtenstein

Robert Giger, Plant Manager
Hansruedi Steiner, Widmer & Ernst
Peter Nold, Widmer & Ernst
Theodor Ernst, Widmer & Ernst
Robert Hardy, U.S. Representative, Widmer & Ernst

Baden-Brugg

Herr E. Leundi, Assistant Plant Manager
Herr Zumbuhl, President, Zweckverband Kericht-Verwertung Region Braden-Brugg
Peter Nold, Engineer, Widmer + Ernst
Theodor Ernst, President, Widmer + Ernst
Robert Hardy, U.S. Representative, Widmer + Ernst

Duesseldorf

- Stadtwerke Duesseldoft
    - Karl-Heinz Thoemen, Works Manager
    - Uwe Anderson, Assistant Works Manager
- Vereinigte Vesselwerke
    - Dr. Werner Schlottman
- Grumman Ecosystems, Inc.
    - Klaus Feindler
- Stadtreining v. Fuhramt
    - Dr. Helmut Orth

Wuppertal

Werner Schlottman, Vereinigte Kesselwerke
Hans Norbisrath, Project Engineer, Vereinigte Kesselwerke
Sedat Temelli, Assistant Plant Manager and Chief Engineer
Klaus Feindler, Grumman Ecosystems, Inc.
Peter Ahrens, Plant Financial Manager
Edgar Buchholz, Plant Technical Manager*
Volkswirt Horst Masanek, Plant Commercial Manager*

Krefeld

Werner Schlottman	Vereinigte Kesselwerke, (VKW), Dusseldorf
Hans Norbisrath	Vereinigte Kesselwerke, (VKW), Dusseldorf
Klaus Feindler	Grumman Ecosystems, Inc., Bethpage, L.I., NY
Jurgen Boehme	Vereinigte Kellelwerke, (VKW), Dusseldorf
Wilhelm Korbel	Krefeld Plant Manager
Heinz Stogmuller	Vereinigte Kesselwerke, (VKW), Dusseldorf

Paris: Issy

M. Defeche	T.I.R.U. Offices, General Manager
M. Jullien	T.I.R.U. Offices, Manager of Technical Services
M. Rameaur	T.I.R.U. Plant, Plant Manager
M. Cherdo	T.I.R.U. Plant, Assistant to the Plant Manager
Walter J. Martin	J. Martin Gmbtt, Munich, W.G.
Sid Malik	Universal Oil Products, Chicago USA
George Stabenow	Consultant to UOP, E. Stroudsburg PA. USA
M.J. Collardeau	Head of the Division "Residus Urbains" (Urban Waste) French Ministere de la Culture et de l'Environment
M. Finet	T.I.R.U. Head of the Division of Pollution Control
M. Monterat	City of Paris, Assistant to the Chief of the Cleaning Service

---

* Mr. Buchholz was interviewed on a previous October, 1976 trip.

** Mr. Masanek was not interviewed but should be mentioned because of his responsibilities.

Hamburg: Stellinger-Moor

Karl Heinz Arndt	Stellinger Moor, Plant Manager
Igor Schmidt	Stellinger Moor, Operations Manager
Hans Rudolf Timm	Stellinger Moor, Maintenance Supervisor
Klaus Von Borck	City of Hamburg, Landfill Engineer
Weiner Gossteuck	City of Hamburg, Chief Construction Engineer
George Stabenow	Consultant to UOP, E. Stroudsburg, Pa., USA
Heinz Weiand	Projects Manager, Martin, Munich, W. Germany

Zurich: Hagenholz

Max Baltensperger	Chief of Waste Disposal and Cleaning (Abfuhrwesen) for City of Zurich
Erich Moser	Technical Assistant Chief
R. Hirt	Professor at Zurich Technical Institute (Conducted study of ash disposal)
Herr Lackmann	Hagenholz Operations Manager
Herr Widmer	Hagenholz Engineering Manager or Administration Manager
Heinz Kauffmann	Projects Manager, Martin, Munich, W. Germany
George Stabenow	Consultant to UOP, East Stroudsburg, Pennsylvania USA
Wettman	?
Herr Puli	Hagenholz Assistant Operations Manager

The Hague

Johan G. Postma	The Hague, Plant Manager, Gemeentelijk Energiebedrijf Vuilverbranding, The Hague, Netherlands
John M. Kehoe, Jr.	Wheelabrator-Frye, Inc., Energy Systems Division, Vice President and General Manager, Hampton, NH, USA
Beat C. Ochse	Von Roll, Ltd., Environmental Eng., Zurich, Switzerland Div., Poject Engineer
Richard Scherrer	Von Roll, Ltd., Environmental Eng., Zurich, Switzerland Div., Project Engineer (now of Widmer & Ernst)

Dieppe (and Deauville)

M. Jean Fossey	Dieppe Plant Manager
M. Bernard Montdesert	Dieppe Plant Chief Engineer
M. Aime Marchand	Director, General des Services techniques, Dieppe
M. Hervee	Asst. Manager, Deauville Plant
Beat C. Ochse	Project Engineer, Von Roll, Ltd., Environ. Eng. Div., Zurich
John M. Kehoe, Jr.	Vice President and General Manager, Wheelabrator-Frye Inc., Energy Systems Div., Hampton, N.H.
David B. Sussman	Project Monitor, U.S. EPA, Resource Recovery Div., Washington, D.C.

Gothenburg: Savenas

Bengt Rundqwist	Director, Gothenburg (Savenas) Plant
Gian Rudlinger	Chief Operating Engineer, Gothenburg (Savenas) Plant
Beat C. Ochse	Project Engineer, Vol Roll, Ltd., Zurich
Kurt Spillman	Project Engineer, Von Roll, Ltd., Zurich

Uppsala

Niels T. Holst	Brunn and Sorensen A/S The Waste Treatmment Department Aaboulevarden 22 8000 Aarhus C, Denmark Telephone: (06) 12 42 33 Telex: 6-45 92

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Bengt Hogberg	Brunn and Sorensen A/S Stockholm Representative
S. A. Alexandersson	Brunn and Sorensen A/S Manager, Waste Treatment Dept.
Hans Nordstrom	Uppsala Plant Engineer Uppsala Kraftvarme AB Sopforbraenningsanlaggningen Bolandsuerket Bolandsgatan Box 125 S-75104 Uppsala, Sweden Telephone: (018) 15 22 20
Hans Nyman	Uppsala Chief Engineer
Karl-ErickBerg	Uppsala Works Engineer
Hans Nomann	Uppsala Managing Director
Hans Sabel	Uppsala Works Director

Horsens

Erling Petersen	City Director of Solid and Water Waste Management
Flinn Larsen	Horsens Plant Manager
Harry Arnum	City Engineer, Horsens
Holger Sorensen	Burgomeister, City of Horsens
Nels Jurgen Herler	Engineer, Horsens Plant
Niels T. Holst	Vice President, Bruun and Sorensen, Aarhus
Paul Sondergaard-Christensen	Engineer, Bruun and Sorensen, Aarhus
Allan Sorensen	Engineer, Bruun and Sorensen Aarhus

Copenhagen: Amager

Gabriel Silva Pinto	Project Manager, Main Plant Layout, Volund
M. Rasmussen	Chief Engineer, Sales Activities Volund
Evald Blach	Former Chief Engineer, Volund
Jorgen Hildebrandt	Plant Manager, Amager Plant
Per Nilsson	Chief of Development Department Civil Engineer of the Renholdnings Selskabet
Thomas Rosenberg	Sales Manager, International Incinerators, Inc., Atlanta, Georgia, Builder of Volund-type systems in North America
Architect	J. Maglebye Architectural Office
Consulting Building Engineers	Ramboll & Hannemann
Consulting Mechanical	Copenhagen Gas and Electricity Services

Copenhagen: West

Mr. G. Baltsen	Director of Copenhagen: West
Gabriel S. Pinto	Project Manager, Main Plant Layout, Volund
M. Rasmussen	Chief Engineer, Sales Activities, Volund
K. Jensleu	Civil Engineer, I/S Vestforbraending, Ejbymosevej 219, 2600 Glostrup, Denmark
e. Blach	Former Chief Engineer, Ex-Volund

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Addresses and Phone Numbers

Refuse Fired Hot Water Generation Plant

Amager Forbraending
Kraftvaerksuej
2300 Kobenhauns
Denmark
Tele: Su 351

Vendor Headquarter

Volund
11 Abildager
Glostrup 2600
Denmark
Tele: 02-452200
Telex: 33150

Collection Organization

Renholdnings Selskabet
Since 1898
Forlandet, 2300 Kbh. S
Amager Island
Copenhagen
Denmark

Danish Boiler Manufacturer's Association

WEKA-VERLAG Gmbh
8901 Kissinng
Augsburgerstrasse 5
Hillerup
Denmark
Tele: 08233-5171

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Waste Management, Inc.
900 Jorie Boulevard · Oak Brook, Illinois 60521 · 312/654-8800

July 30, 1979

U.S. Environmental Protection Agency
Resource Recovery Division A-W 462
Washington, D.C. 20460

Attention: David B. Sussman

Re: Contract No. 68-01-4376

Dear Mr. Sussman:

We at Waste Management, Inc. appreciate being given the opportunity to review the draft of the extensive report prepared by Philip Beltz and his staff at Battelle.

Prior to offering our comments, two statements must be made and accepted. Firstly, that Waste Management, Inc., through its license agreement with Volund, is committed to the concept of mass-burning of municipal refuse using refractory-walled furnaces, and is thus necessarily biased in its judgement, and secondly that the Battelle staff, while having spent a considerable period gleaning information from the constructors and operators of energy conversion plants, have nevertheless colored the content of the report to reflect their own conclusions and opinions. No one can inspect so many operations without developing a preference for a certain system and certainly the editorialising and definitive statements within the report reflect this.

Insofar as the folks at Battelle have been contracted to do just this, it would be inappropriate to argue with their preference, except where statements made in the text are either incorrect or need considerable qualification. This is where we have tried to be of assistance in rendering this report to be the valuable, accurate reference book that it should be.

Specifically, our comments are these:

Ref. p. A.1. par. 3 and 5. "The early units were refractory-walled and thus the steam quality (temperature and pressure) was limited." and "the water-tube wall furnace/boiler" has the refuse combustion section surrounded by vertical or sloping steel tubes in parallel.......generate a major fraction of the steam produced. This increases efficiency and allows a much higher quality steam to be produced.

Steam is generated by the transfer of heat from flue gas (the product of the refuse combustion) to water, via the metal walls of boiler tubes. The efficiency of the boiler is a function of the gas flow pattern and the tube metal surface area. The quality of steam produced is determined by the feed-water pressure, tube wall thickness and location and size of the superheater.

Whether a furnace utilizes a refractory-walled or water-walled combustion chamber is of absolutely no consequence in the final quality (temperature and pressure) of the steam.

Most European incinerators incorporate Eckrohr boilers and it is these devices alone which determine the steam quality, not the combustion system.

The question of whether or not there may be advantages from an efficiency point of view between the two systems is discussed in the attached paper written by Gunnar Kjaer of Volund U.S.A.

Ref. p.A.27. The refractory wall furnaces are generally less expensive and would have technical difficulties raising steam temperatures to much above 260C (500F).

Until the nineteen-fifties, refractory-wall furnaces were the major system utilized throughout the world for raising steam, using all fuels from refuse to coal and oil. Steam temperatures and pressures were determined by the design of the boiler alone and are not in any way affected by the nature of the combustion zone construction.

Steam temperatures in excess of 1000°F are commonplace in boilers with refractory walled furnaces.

The major consideration in refuse-fired furnaces is the quality of the flue gas (which is the same regardless of whether refractory or water wall furnace is employed.) When tube-metal temperatures exceed 700°F, extensive chloride corrosion occurs so that a selection must be made between high steam temperatures (and the attendant high turbine efficiencies) or low maintenance costs associated with low-temperature operations.

There is no technical difficulty whatsoever in generating high temperature steam with a refractory-wall furnace. It is simply poor practice, as the repeated failures in operating water-wall units has demonstrated.

Ref. p.A-53. Pit Doors
It is our opinion that this section should also address the common European practice of piling the refuse above the level of the closed doors in order to further utilize the available hopper capacity.

Ref. p.A-58. Kockum-Landsverk was a Swedish company (formerly a licensee of Volund) and is no longer in the incineration business.

Volund is represented in the United States solely by Volund U.S.A. (VUSA), with whom Waste Management, Inc. has a marketing agreement.

Ref. p.A-103 par. 5 and 6 infer a clear division between the capabilities of refractory-wall and water-wall furnace systems.

In fact, some waterwall manufacturers have chosen to offer units generating high-pressure steam, while some refractory wall manufacturers have preferred to offer only low temperature systems. The decision, as discussed in earlier pages, is based soley on economic implications - higher temperature steam means higher tube failure rate and thus higher operating costs regardless of which system is used.

Within Secion B, Gunnar Kjaer of Volund U.S.A. has identified a number of specific errors in the inventory tabulation which are listed below:

The following comments serve to correct some of the inaccuracies in the list of Refuse-Fired Energy Systems. The corrections apply primarily to

Denmark and Sweden, in which countries I have intimate knowledge of the refuse-incineration market. However, it may be assumed that other geographical areas of the world also need further scrutiny before the lists and the book are sufficiently correct to justify publication.

The comments relate to the plants as numbered on the attached copy of the list.

DENMARK

Plant No. 1, 2 and 3 (Aalborg): This is one plant with two lines, installed in the buildings of a former compost producing plant. Line No. 1 was designed and installed by E. Rasmussen in 1968 using a Flynn & Emrich grate design. The technical data given under plant No. 1 are correct. E. Rasmussen incinerator division was acquired by Bruun & Sorensen in 1970. Since 1973, line No. 1 has been on stand-by only. Line No. 2 was designed and installed by Vølund in 1972 and the technical data given under plant No. 2 in the list are correct. Plant No. 3, Aalborg, does not exist, but is a (partly erroneous) duplication of the information under (1).

A completely new plant, Aalborg II, is presently being installed and will be operating in 1980. It is designed, manufactured and constructed by Vølund and will have 2 lines, each 8 M.T./hr. and will produce high pressure hot water for district heating. The building, now near its completion, will have room for a total of 4 lines, each with 10 M.T./hr. capacity.

Plant No. 5 and Plant No. 39 are the same plant. Correct "date begin operation" is 1969. Location: City of Aarhus in an area within the city known as Tilst.

Plant No. 7: Correct name of location: Brøndby. Second line of same capacity begins operation in 1979.

Plant No. 12, Frederiksberg: Heat medium - steam for district heating (each boiler 7.5 t/hr., 12 bar, 190°C, 17000 lbs./hr., 178 psi, 375°F).

Plant No. 14, Gentofte: Heat medium - steam for electricity generation (each boiler 7.5 t/hr., 14 bar, 350°C, 17000 lbs/hr., 210 psi, 660°F).

Plant No. 17, Herning: The first 3 t/hr. line was installed in an existing gas work building and began operation in 1964. It was closed down and demolished in 1971 following the start of operation of the first line of a completely new plant in a different location, Herning II. This new plant had one line, capacity 3 t/hr., to be followed in 1973 by a second line, capacity 4 t/hr.

Plant No. 19 is the same as plant No. 38. Location: Taastrup. Technical data given under No. 19 are correct.

Plant No. 21, Horsens: Capacity 5 t/hr., 120 M.tpd.

Plant No. 26, Nyborg (Kommunekemi): No electricity production, but use of steam for internal use with balance being sold to the hot water district heating scheme via a heat exchanger.

Plant No. 28, Odense-Dalum: Closed down in 1972.

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Plant No. 33 and 34 are two lines in the same plant. Technical data are correct. However, the first line, 3t/hr., was installed by B & S in 1970 and the second line, 4 t/hr., was installed by Vølund in 1973.

Plant No. 36 and 37 are two lines in the same builing.

Plant No. 40, Weston: Energy - high pressure hot water for industrial use.

It should finally be mentioned that Danish environmental standards distinguish between plants with refuse handling capacities over and under 5 metric t/hr. For plants handling more than 5 M. t/hr., particulate emission is limited to 0.065 grains/dscf at 7% CO_2. This standard can not be met by the mechanical type filter (multicyclones, etc.) installed in many smaller plants built before the present guide lines were introduced in 1974.

Therefore, many of the smaller plants are restricted, even where duplicate lines have been installed, to operate one line only, at any given time in order to keep hourly throughput below the 5 M.t/hr. limit. This applies to plants No.'s 1, 11, 13, 15, 16, 17, 18, 20, 23, 25, 27, 30, 31, 33-34 and 36-37.

On this basis, daily rated capacity per system for these plants perhaps should be that of one unit.

SWEDEN

Plant No. 1, Boras: Heat medium - steam, 10.3 + 10.3 + 16.5 M.t/hr., 10 bar, 285°C (22700 + 22700 + 36500 lbs./hr., 150 psi, 545°F). Cogeneration of electricity and H.P.H.W. district heating.

Plant No. 8 and 9, Linkoping, are three lines in the same plant.

Plant No. 10, Stockholm-Lovsta: Built by Vølund-Landsverk in 1938. Refractory wall furnace, refuse-fired hot air generator. Plant burns H, C, LI. Capacity: 4 lines each 7.5 M.t/hr. Originally electricity generation. Line No. 5, 12.5 M.t/hr. installed in 1965 by Vølund-Landsverk. In 1968 two lines were fitted with rotary type dryers for thermal drying of non-dewatered, digested sludge. Designer/Manufacturer: AB Torkapparater, Stockholm.

Plant No. 11, Lulea: Duplicate information. For correct information, see plant No. 12.

Plant No. 12, Lulea: Is correct with the following additions: In addition to the production of hot water for district heating this plant uses the combustion gases to dry undewatered sludge in rotary type dryers supplied by AB Torkapparater, Stockholm.

Plant No. 14, Sodra Sotenas: Location in the Gothenburg Archipelago. To the best of my knowledge, there is no energy utlization.

Plant No. 21 and 22, Stockholm-Solna are the same plant: Two lines have been refurbished by B & S as mentioned under Plant No. 22. Total capacity, 3 x 4 Mt/hr.

Plant No. 25, Sundsvall: Steam is used for electricity production and industrial process steam.

UNITED KINGDOM:

Coventry: Unless recent modifications have taken place, no electricty is generated, but steam is used for internal use, driving fans, hydraulic pumps, etc. via individual direct drive steam turbines. In addition, energy is sold for indutrial space heating for the nearby Chrysler car factory.

FRANCE:

Paris-Ivry: The furnace capacity of this plant has been downrated from 2 x 50 M.t/hr to 2 x 40 M.t/hr. following modifications of the water wall furnaces.

Finally, please note that Table A-25 incorrectly informs that Copenhagen Amager and Copenhagen West produce steam.

The succesive sections relate to actual information received from local contacts during the survey, and are beyond our perview to comment.

We would caution, however, that such comments as appear on page X-16; The appearance of the stack plume was extremely clean and attractive and the stack plume was usually invisible. are necessarily subjective and while we do not question the interpretation (on a two day visit with periodic observation) we cannot help believing that these statements color and prejudge actual long-term performance of the systems.

We hope that our comments together with those of our Danish collegues (being sent direct) are helpful to you in finalizing the report.

Regards,

Gunnar Kjaer
President, Volund U.S.A.

pp Peter J. Ware
Director of Enginering
Waste Management, Inc.

cc: Philip R. Beltz
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Please note also the attached comments, Ref. page A-103, paragraph 7.

June 28, 1979

Waterwall Furnaces vs. Refractory Lined Furnaces

The advantages and disadvantages of waterwall cooled incinerators compared with refractory lined incinerators has been debated in Europe for nearly two decades. Prior to the late 50's refuse incineration furnaces were, as a matter of course, built with refractory lined walls. It was widely accepted that the primary purpose of the refuse incinerator was to dispose of refuse. That refuse incineration is best accomplished in a refractory lined furnace has never been disputed. This is because the high heat capacity of the refractory lining keeps the combustion process going, even when charges of low heat value refuse (due to high moisture or high ash content) are fed into the furnace.

The radiation heat from the furnace walls enable the incinerator to handle portions of refuse which are not, in themselves, autocombustible. The result is the maximization of volume reduction and a residue with a minimum content of putrescible matter and unburned carbon.

The refractory lined furnace was to some extent, perhaps, more necessary in the 40's and 50's than today because of the lower heat value of the refuse at that time and the different composition.

Refuse in the Western industrialized world has changed considerably since the 40's and 50's, in quantity as well as in composition. The ash and putrescible content has been reduced. The considerable increase in refuse quantities that has taken place is, generally, in the form of highly volatile material, i.e. paper and plastic. The result is a much higher overall heat release from each ton of refuse. However, with so much of the heat value tied up with the high volatile matter, the stabilizing effect produced by refractory brickwork in the furnace is desireable in order to burn the less combustible portion.

Another result of the increasing refuse quantities in the late 50's and 60's has been a demand for larger units. In Europe energy utilization from the refuse has been a matter of course ever since the Vølund company built the world's first continuously operating incinerator in Denmark in 1930. This unit produced electricity from the refuse. Vølund and most of its licensees as well as newcomers

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to the European incineration field have generally subscribed to the idea of heat utilization from the refuse. However, Vølund was for a long time the only company with in-house expertise and experience in both boiler design and manufacture as well as in incinerator design and manufacture.

As a result, most other incineration plant designs have been based on experience gained from boilers for conventional solid fuels and not on experience with solid waste. Thus, we find that these systems tend to reflect primarily traditional boiler design requirements such as:

-- High efficiency

-- High pressure stability, i.e. the ability to withstand the required static pressure on the water/steam side with minimum use of material in boiler tube walls.

-- Good steam quality without water droplets.

Only rarely, however, has adequate consideration been given to the special thermal conditions applicable to the incineration of domestic refuse. This became even more evident as larger incinerator units were required which began to approach the size of small power station boilers.

This has resulted in essentially conventional power plant boilers been constructed with an incineration grate included. Serious corrosion problems have plagued many of these systems along with problems resulting from slagging and sintering of ash and clinker on the boiler surface after only a few years of operation.

Dew point corrosion, in plants with heat utilization is rare in boilers or in auxiliary equipment, i.e. gas ducts, electrostatic precipitators or I.D. fans. The exhaust gas temperature can easily be maintained well above the dew point temperature for the acids and the flue gases.

High temperature corrosion, on the other hand, presents a serious threat to the availability and also to the operational efficiency of the plant.

The reasons for high temperature corrosion are, today, well understood, and it is generally agreed that the following conditions should be avoided:

-- The presence of local streaks of incompletely burnt gases in the gas passages of the boiler.

- -- Boiler wall temperatures (metal temperatures) exceeding 350-400° C. (650-750° F.)
- -- The presence of a layer of flyash or clinker in a melting phase on the boiler surface.

Recent investigation indicate that the most dangerous conditions are caused when incompletely burned-out gases come in contact with the boiler walls thereby causing fluctuation between oxidizing and reducing atmospheres in the presence of high temperatures and corrosive gases. If these streaks of reducing atmosphere can be avoided then the metal temperature in itself seems less important.

The occurence of melting temperatures in the flyash and clinker layer, too, is often caused by this local combustion of unburned gases raising the temperature locally above the melting point.

It is, therefore, very important to avoid the streaks of reducing atmosphere in the boiler. This problem must be solved before the gas reaches the boiler rather than in the boiler itself.

Despite all efforts to mix the waste properly before it is fired into the furnace, waste remains a very heterogeneous fuel which burns with varying velocities and oxygen requirements. Therefore, local streaks of unburned gases with high carbon monoxide content as well as temperature fluctuations will occur immediately above the grate, despite the presence of excess air. These conditions are further promoted by the very wide grate areas necessary in high capacity incinerators.

Gases only mix effectively when they are of the same temperature. Therefore, the combustion gases must be retained in the combustion zone long enough to ensure that the gases are completely burned out and properly mixed so that a homogeneous oxidizing atmosphere is created prior to entering the boiler.

Vølund's two-way gas system and the special after-burning chamber allows the time, temperature and turbulence necessary for complete combustion of the gases before they enter the boiler.

The flyash particles consist mainly of easily meltable clinker, which remain "soft" down to a temperature of approximately 600° C. (1100° F.). Even after the surface of the flyash particles is cooled below that temperature, the center remains soft for some time, increasing the risk of the particles sticking to the boiler surface when they flatten on impact.

The degree of clinker slagging and sintering is often the decisive factor in determining when an incinerator must be taken out of operation for maintenance. Therefore, it is important that flyash particles are burned out completely and are effectively cooled down before entering the convection part of the boiler, where the boiler tubes are positioned.

The first objective is achieved in the after-burning chamber. The second is met by designing the gas passages to allow sufficient time in the radiation zone of the boiler.

These objectives, we believe, are best achieved through a design incorporating a separate furnace and boiler. Compared with the integrated boiler design (water-wall furnace) the separate furnace and boiler design generally requires a marginally higher investment and, in addition, the heat recovery is, in theory, of marginally lower efficiency.

However, when operating costs are considered, the economics change dramatically. The ultimate decision is between marginal theoretical efficiency -- and reliability and availability.

Today, few, if any European incinerator designer/manufacturers still offer a pure water-wall furnace for incineration of urban refuse. Furthermore, specification for maximum steam outlet temperatures from incinerators are frequently being downgraded to 650-750° F following the many incidents of serious superheater corrosion experienced over the last 10 years or so.

Existing water-wall furnaces in operation in Europe have experienced severe erosion and corrosion problems in the water-wall sections. This has largely been a result of the previously mentioned fluctuation between oxidizing and reducing gas atmospheres in the furnace. Theoretically, the water-wall incinerator furnace can be operated with less excess air than the refractory wall incinerator because no air cooling is required for the furnace walls. It is this theoretical reduction in excess air that has produced the marginally higher fuel-to-energy efficiency.

However, the problem of corrosion of the water-walls has caused the plant operators and designers to increase substantially the amount of excess air, resulting in the elimination of this marginal boiler efficiency. Unfortunately, in most cases, increasing the excess air has not been sufficient to solve the corrosion problem.

Water-wall manufacturers, therefore, have now begun to install refractory linings inside the water walls in the furnaces. The immediate effect has been a reduction in furnace throughput capacity. For instance, the very large water-wall furnaces at the Ivry Incineration Plant in Paris have had their capacity ratings reduced from 50 to 40 metric tons per hour (1320 to 1056 short tons per day per unit) as a result of the relining required to deal with corrosion problems. In addition, fuel to energy efficiency has, of course, been reduced as well.

New so-called water-wall furnaces are, today, as a matter of course being designed with a refractory lining up to the end of the combustion zone. However, in a recent paper presented at the meeting of the Corner Tube Boiler Manufacturers' Association, a representative of one of the leading manufacturers of water-wall furnaces pointed to the still existing risk of corrosion in water-wall furnaces as a result of cracks in the refractory lining. It was pointed out that this corrosion would occur mainly in the areas where the refractory supports are welded to the water wall.

The same manufacturer according to a study completed for the U.S. Energy Research and Development Administration, (now Dept. of Energy) acknowledges the advantage of the refractory furnaces with respect to reliability. A previous incineration plant with refractory lined furnaces built by this company in Lausanne, Switzerland is now nearly 20 years old and is still available nearly 90 per cent of the time. The best that the same company has ever achieved with their early water-wall furnace designs has been about 75 per cent availability, and even today with their modernized water-wall designs the company will not guarantee more than 80 per cent availability.

Today, even where water-wall furnaces are installed in Europe most are refractory lined in the combustion zone. While the theoretically higher efficiency has been diminisned by the design changes required by the problems discussed above, modified water-wall furnaces are still being specified by some consultants. It is understandable, given the time delay between European and American experience in incineration technology, that it will still be sometime before the North American market focuses on the greater reliability and actual fuel-to-energy efficiency of the refractory lined incinerator furnace.

Gunnar Kjaer

UOP Inc.
Environmental Systems Group
40 UOP Plaza—Algonquin & Mt. Prospect Roads
Des Plaines, Illinois 60016
Telephone 312-391-2341

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August 30, 1979

Mr. David B. Sussman
Resource Recovery Division (AW-462)
U.S. Environmental Protection Agency
Washington, D.C. 20460

SUBJECT: Evaluation of European Refuse-Fired Energy Systems Design Practices. Review of Draft Report Volumes I to IV

Dear Mr. Sussman:

In accordance with your request, both UOP Inc. Solid Waste Systems and our technical collaborators, Josef Martin Company of Munich, West Germany, have reviewed the subject report prepared by Battelle Columbus Laboratories.

Josef Martin Company's review and comments were airmailed to you directly from Germany on August 22, 1979, with a copy to us. We have reviewed these comments and fully concur with Martin. In addition, we have also noted a few typographic errors, which we are sure will be corrected in editing. We have also observed that some tables have lost legibility in size reduction and printing, particularly Table A-15 on page A-40 and Table A-17 on page A-47.

On page A-54, paragraph two, the sentence after, "since all of ---" is not clear. The statement appears to imply "one of the units at most plants is down at all times." We suggest this sentence should be re-written to read, "For the purposes of scheduled maintenance, when one of the units is shut-down and remaining unit(s) cannot process all the refuse delivered at the plant, a pit capacity of 5-6 days storage is normally provided."

On page A-55, the first paragraph, second sentence states, "The most used shear is manufactured by Von Roll." This statement appears questionable. We assume the authors mean that all of the Von Roll plants visited had shears manufactured by Von Roll.

On Table A-21, page A-58, "Universal Oil Products" should read "UOP Inc."

On page A-59, second paragraph, "range in rates" should read "ratio of rates."

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Page A-64, Table A-23, first line "room" should read "Ram."

Page A-71, Table A-24 - Overfire air per tonne for Paris Issy plant appears to be too high. Appears total combustion air (4235 M^3) is shown as overfire. Only 20-25% of combustion air is used as overfire.

We appreciate the opportunity of being allowed to review the subject draft report and hope you will find our comments useful.

We commend you and the authors of this most comprehensive report on Europea technology.

Very truly yours,

R.W. Seelinger

R. W. Seelinger
Engineering Manager
Solid Waste Systems

pt

c: Josef Martin Co.

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JOSEF MARTIN FEUERUNGSBAU GMBH
MÜLLVERBRENNUNGSANLAGEN – RÜCKSCHUBROSTE – ENTSCHLACKER

1925 50 1975

Josef Martin Feuerungsbau GmbH, Postf. 40 12 29, 8 München 40

Mit Luftpost - By airmail

Mr. David B. Sussman
Resource Recovery Division
(AW 462)
U.S. Environmental Protection Agency
Washington, D.C. 20460
U.S.A.

Ihr Zeichen	Ihre Nachricht vom	Unser Zeichen	München Leopoldstr. 248
		Wd/AH	22 August, 1979

SUBJECT: Battelle Laboratories
Report: Evaluation of European Refuse-Fired
Energy Systems Design Practices

Dear Mr. Sussman:

We refer to your recent agreement with Mr. Phil Beltz of Battelle covering possible corrections of the above-mentioned report. This report reached us only on 31 July 1979 so that the short period (deadline: 31 August 1979) indicated by you for submission of suggested corrections, allowed only a perusal for basic errors and misunderstandings and no thorough discussion.

We would praise the Battelle authors for their thorough and detailed summary and discussion of all technical information gathered on the occasion of their visits to the various European refuse incineration plants with generation of energy. It is understandable that in view of the great number of data confusions or mistakes crept into now and then, especially since there was the problem of the different languages, too.

.../2

Our perusal of the 4 volumes has mainly been concentrated on the passages referring to plants of the Martin system. Sometimes, we have also commented on general theories and philosophies of Battelle, however, would clearly state that we do not always share the authors' opinions.

We were somewhat disappointed at the fact to find again a great part of the errors and mistakes already contained in the preceding trip reports of Hamburg-Stellinger Moor, Paris-Issy-les-Moulineaux and Zurich-Hagenholz and meanwhile corrected with our letters dated 22, 23 and 26 February 1979.

Also the corrections submitted by TIRU in their letter to Battelle dt. 23 February 1979 have not been considered.

Due to the short period allowed to us we have no possibility of discussing this report with the plant managers of the 3 Martin plants mentioned. Therefore, we are not in a position to judge whether our clients agree to publications of data covering, for example, capital and operating costs or of way of financing. We hope that Battelle has obtained our clients' permission.

Furthermore, we have not corrected any misprints nor translation errors.

We are enclosing photostats of the pages where we have made corrections (marked in pink).

We kindly ask you or Battelle to modify the corresponding pages of the draft report to the effect of real information.

.../3

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We would still briefly comment on a few pages, as follows:

Pages A-1, A-66, A-67, A-103, I-2, S-4, U-8

A great misunderstanding seems to have crept into here in so far as Mr. Tanner is called the originator of the modern-day water-tube wall refuse incinerator/boiler. Mr. Tanner may be called the originator of the waste heat boiler for refuse incineration plants, however, never the originator of the modern-day water-tube wall refuse incinerator/boiler. You may look this up in the two publications mentioned by Battelle on page A-67. Many years before Von Roll, Martin have equipped the furnace walls with boiler water tubes and this was severely criticized by Von Roll in competitions.

Page A-4

The quantity burned by the Hamburg-Stellinger Moor plant in 1976 was 200,556 mt refuse. The quantity of 420,680 mt indicated by Battelle refers to both Hamburg refuse incineration plants (Stellinger Moor and Borsigstrasse).

Pages A-61 and Q-8

I. On Hamburg-Stellinger Moor

Battelle has obviously misinterpreted an information obtained from Hamburg-Stellinger Moor. From the beginning of commissioning up to the year 1976, always individual grate bars only had been replaced, if required, during the annual maintenance periods of the stoker firing equipment in Hamburg-Stellinger Moor. From the year 1976 onwards, however, this maintenance schedule has been changed.

.../4

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Since 1976, during the annual shut-downs for maintenance, it is no longer usual to replace individual grate bars, but to replace complete grate bar steps. Each step consists of 25 grate bars. The removed grate steps are refurnished in the plant's own workshop, individual grate bars are replaced, if required, and then the refurnished steps are held ready for the next maintenance shut-down. In the first year (1976) this procedure was applied, a great many bars, viz 24 % mentioned by Battelle, were replaced. In the second year, only 15 %, in the third year 1978 only 10.5 % were replaced, and it is expected that the replacement rate will go down to a figure from 5 to 10 % in the course of further operating years.

The above information was confirmed to us by the Hamburg-Stellinger Moor plant management on 22 August 1979 over the phone.

You will certainly agree with us that we demand that the figure of 24 % indicated by Battelle in the report, is changed to "less than 10 %", as it is completely wrong and may even do harm to our reputation, as compared to our competitors.

2. Zurich-Hagenholz

Also the figure of 7 % mentioned here is wrong. Upon inquiry, the plant management confirmed us on 22 August 1979 over the phone that within 40,000 operating hours only 32 grate bars were replaced, thus only approx. 0.8 %/year. The figure of 7 % indicated by Battelle is a composite value of all spare grate bars of the two older Von Roll units No. 1 and No. 2 and of the Martin unit No. 3. Here, too, we demand correction.

.../5

Page G-3

Contrary to Kaiser and Perry we have found out that in case of municipal refuse the difference between higher heating value HHV and lower heating value LHV is approx. 10 to 15 %:

For example:

for refuse at about HHV = 5000 Btu/lb the difference is approx. 11 %

for refuse at about HHV = 4000 Btu/lb the difference is approx. 15 %

Therefore, the formulas indicated by Battelle are very doubtful.

Pages R-10 and R-13

The photo R-7 shows a Martin ash discharger of the Bazenheid/Switzerland refuse incineration plant.

Here, too, we demand correction.

Page S-58

We think it necessary to clarify the term "Combustion Volume", otherwise the volume heat release ratesmentioned in table S-3 are not comparable.

Page U-27

The furnace roof tubes are part of the first stage superheater, are thus flown through by saturated steam or some-

.../6

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what superheated steam. During start-up or shut-down of the boiler, radiation and too low a steam flow may cause local overheating of the tube wall, resulting in wall thickness reduction in the course of time. These tubes were never covered with SiC material.

Pages U-81 and U-83

The Yokohama-Totsuka plant has a completely different superheater design and should not be mentioned in this connection.

Page X-3

The regulation "TA-Luft" refers the indicated emissions to 11 % O_2, and not to 7 % CO_2.

We hope that you or Battelle will still make the corrections mentioned above and indicated on the enclosed photostats, if not, the value of the otherwise quite good Battelle report would be reduced considerably.

Very truly yours,
JOSEF MARTIN
Feuerungsbau G.m.b.H.

ppa.:

ENCLOSURES

M 58

Wheelabrator-Frye Inc.
ENERGY SYSTEMS DIVISION
Liberty Lane
Hampton, New Hampshire 03842
Tel. (603) 926-5911

JOSEPH FERRANTE, JR.
Regional Vice President

September 12, 1979

Mr. Philip R. Beltz
Projects Manager
Energy and Environmental
Systems Assessment Section
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Dear Phil:

You are in receipt of Von Roll's August 20th comments to your draft report, entitled "European Refuse-Fired Energy Systems - An Evaluation of Design Practices". The purpose of this letter is to relate some of our reactions to Volume I of this four-volume effort. I have also attached a copy of Von Roll's remarks which we received. I believe they are similar, if not identical, to the ones you already have.

In general, the report is excellent and makes a substantial contribution to the literature dealing with the subject. The following are some points to clarify to avoid misleading the uninformed reader.

- The inference is made that the approach to be used in Harrisburg is new. In reality, the use of steam to buildings' adsorption chillers is not new and has been widely practiced in major cities in the U.S. including New York and Boston. The second paragraph is therefore misleading. (Page A-33).

- Although "spending money for features to reduce corrosion and erosion generally increases investment" is true, it is a worthwhile investment to do so. The impact of the additional investment is minimal in comparison with the costs to maintain and replace boiler tubes without corrosion reduction features. (Page A-45, First Paragraph).

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- It is not only the tax free bonding which favors private ownership in America; rather investment tax credits and accelerated depreciation are very important in making the private ownership decision. (Page A-46, Paragraph 2).
- It should be noted that in a third Munich unit, refuse is fired separately with coal. Munich has since concluded that coal and municipal solid waste should not be co-fired. (Page A-68).
- The second to the last paragraph should read "when Wheelabrator-Frye Inc. built the Boston North Shore plant in Saugus, Massachusetts, using the Von Roll design..." (Page A-72).
- The expression, "American thrust towards co-firing" is an overstatement. This should read, "... some of the American experimental efforts towards co-firing..." The inference that there is an American thurst in moving towards co-firing is not wholly justifiable. (Page A-92, Fourth Bullet).
- The dump fee costs indicated are misleading in that they suggest that they are real costs. In actuality, the disposal costs are much higher. (Page A-99, Second Bullet).
- It is misleading to suggest that the tipping floor method is an "American" system when in reality, the pit and crane method is more prevalent. The tipping floor method should not be given the characterization "American." (Page A-99, Next to Last Paragraph).
- The listing of U.S. installations is very misleading in that it includes:
    - Proposed projects which may never be built.
    - Projects which have been abandoned.
    - Non-municipal waste projects.
    - Non-energy recovery projects.
    - Experiments.

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To include as comprehensive a list is not justifiable in a report on refuse-fired energy systems, since it leaves the impression that the U.S. has 89 implemented systems, when in reality there are less than 20 bona-fide refuse-to-energy projects in the U.S. Furthermore, the U.S. listing is not compatible with listings of other nations since it includes proposed projects, non-energy recovery projects, etc.

To leave the listing of U.S. systems in its present form would be a detriment to the report. (Pages B-57 - B-67).

- Why are Martin plants referenced as such in the report, while other manufacturers' plants are only referred to by the city in which they are located? The editors should be consistent. (Page I-29).

We trust that these comments can somehow be incorporated in your final report to EPA and appreciate the opportunity to have been involved in this project.

Sincerely,

Joseph Ferrante, Jr.

/pcl

cc: David Sussman

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VON ROLL COMMENTS ON THE BATTELLE REPORT ON EUROPEAN REFUSE-FIRED ENERGY SYSTEMS

(Transcribed from Telex received 08/21/79)

As your just finished and very detailed report is mainly a tool for decision making for now and for the future, we think it is very essential, that as far as Von Roll's grate design is concerned, the report should concentrate on the design Von Roll is now applying and should report on the design given up by Von Roll in 1978 and inspected in the four rather old plants, only as far as it is necessary for a better understanding of our design applied now. We have discussed this problem with you and you have promised to consider a rewriting of the pages Q-9 to Q-14 due to the very short time, Von Roll had available for reviewing the entire report we are concentrating on the key items of our design, the grates and boiler. We ask you to use the following text for replacing the existing version in your report:

Von Roll Grate

1. Figures: Please change figures as follows:

Figure Q-2: Two steps of Von Roll Grate using reciprocating forward-feed design. (Courtesy of Von Roll Ltd.)

(Picture as shown in draft under Figure Q-3.)

Figure Q-3: Improved Von Roll reciprocating step grate in refractory walled furnace. (Courtesy of Von Roll Ltd.)

(Picture as shown in draft under Figure Q-2.)

2. Text for Pages Q-9 to Q-14:

Figure Q-2 shows in more detail the old standard Von Roll sloping reciprocating grate as it is used in most of Von Roll plants built before 1978. This original Von Roll grate, which is still in use in many of the larger Von Roll plants involves the alternating forward motion of adjacent grate "plates".

For smaller furnaces (that is 5 tons per hour or less) and particularly also for high calorific value trade waste Von Roll began 15 years ago install an improved grate composed of alternate fixed and moving rows in which each entire moving row of grate plates moves forward and backward together, thus eliminating the relative motion and grinding action between adjacent grate blocks. Von Roll is now applying this design to all new furnaces regardless of size. For existing plants, a grate system was developed by Von Roll, which can be mounted on top of the existing grate understructure and several plants have been modified in the meanwhile. Figure Q-3 shows a section of the modified grate at the Von Roll Gothenburg plant.

For new plants Von Roll developed the R-grate. A prototype of this grate is in operation since 1976 at the Von Roll Fribourg plant in Switzerland. The new system consists of a hydraulically driven feeding ram for volumetric charging and of a grate 6 to 12 meters long, 1.8 to 10.5 meters wide and with a declination of 18 degrees. The grate is built-up by 3 to 24 identical grate units linked together. For average and high heating values no grate steps are provided anymore, as this was done by Von Roll in its older design (see figure Q-2). For low heating values, however, grate drops still are provided also at the new R-grate to rearrange the heavy fuel bed as it tumbles down from an upper to a lower grate. Because of the "opening up" of unburned combustible surfaces as this tumbling action occurs, this point is in the furnace, one of the intense burning. To provide enough air at this point, in some plants, air is being admitted through the wall of the step to assure amply oxygen supply for the increased combustion rate.

The grate unit is the basic unit of the new R-grate system. Each unit consists of support structure, lateral sealing elements, four fixed transversal grate support, hoppers, zone separation walls and hydraulic drive units. The so-called drive carriage with the four mobile transversal grate support beams connected to the hydraulic drive is mounted on the support structure. The grate blocks are mounted on the fixed as well as on the mobile transversal grate support beams.

The drive carriage moving the four mobile rows of blocks is equipped with rollers running on inclined guiding tracks and supported by the two parallel longitudinal frame elements of the carriage. The guiding tracks are mounted on the longitudinal supports of the support frame.

The hollow grate block is equipped with cooling fins, enables forced cooling resulting in reduced wear and increased life span. The blowing of primary air through rectangular openings cast into the grate blocks results in high pressure loss enabling uniform distribution of the combustion air throughout the fuel bed independent from its thickness or distribution on the grate surface. Even substantial variations of the fuel bed do not change the uniformity of air

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distribution apart from negligible deviations. The chrome steel cast grate blocks are laterally machined. Each row of blocks is individually clamped together. Approx. 1,5 0/0 of the total grate surface of one section consists of air outlets.

The clamping device of the mobile block rows consists of two identical clamping brackets holding the clamping pins and the tie rods. The locking brackets are inserted in the first and last block of each row and frictionally connected by the tie rods located underneath the grate blocks. The fixed rows of grate blocks are locked in a similar way. This locking system reduces on one hand grate riddlings to a minimum, on the other the blocks remain firmly pressed together even in operating condition, preventing undesirable escape of air between them and securing continuous forced cooling.

The grate drive is hydraulic. Each grate unit is driven by two parallel cylinders mounted on the two lateral longitudinal supports of the support construction. The cylinder rods are connected to the drive carriage by shackle joints and move it for and back on the inclined guiding tracks. The grate blocks supported by the transversal beams move in the same rythm. The angular grate block form and the rapid stroke movement result in an excellent shifting and stoking effect. The fire spread evenly across the entire width of the grate at minimum dust development.

This grate drive system enables utilization of small and lightweight drive cylinders (approx. 16 kg/cylinder) for easy and quick exchange. Mounting or removal of a cylinder can be effected during operation owing to the newly developed drive and control system enabling control of each single drive unit separately. Therefore grates consisting of several grate units may operate at reduced load even during exchange of a cylinder.

The drive of the individual grate unit is not continuous as usual for today's systems but by electronic impulse control. Each grate sections is assigned the most suitable number of strokes depending on average waste heating value and progress of combustion. This number of impulses determines the respective waste travelling speed in the range of the respective grate unit. Based on combustion progress the optimum number of impulses is determined and adjusted for each grate section.

By this system the impulse number (number of strokes) of the whole grate can be uniformly increased or reduced for respective throughput alterations. The relation of the operating speed of the individual grate units, however, remains unchanged.

Owing to the application of electronic components it is possible at any time during operation to change the respective number of impulses of individual grate sections. Grates in boilers for heat recovery may for instance be controlled relative to the steam production by controlling the intervals between strokes.

Automatic firing control facilitates operation considerably since the operating staff has to control manually only in the case of a change of throughput.

Feeding Ram

Most important prerequisite of any automatic operation is uniform feeding. Von Roll applies a hydraulically driven feeding ram. It can be best compared with a drawer turned upside down. This drawer moves on a horizontal surface. The stroke speed is continuously variable by a remote oil flow control. The back stroke is effected at constant speed. Similar to the grate the ram is controlled with respect to steam production. Contrary to the grate, however, the stoke speed is continuously adjusted without any significant alteration of the waste quantity per stroke.

General Boiler Design

(Page U-8 to U-10)

Von Roll would like to comment, that the so-called tail-end boiler, consisting of a vertical waterwall combustion room and a horizontal convection section with hanging vertical tube bundles is a Von Roll development, applied first in the Lnadshut and in the Fuerth plant in Germany in 1971. A special feature of this boiler type is its inexpensive mechanical boiler cleaning by rapping of the bundles. This design is a very successful improvement towards high boiler availability. Since Landshut, Von Roll provided this boiler type for the plants in Mulhouse, France (1972), Quebec, Canada (1974), Angers, France (1974), Dijon, France (1974), Nyborg, Denmark (1975), Bezons, France (1975), Kempton, Germany (1975), Saugus, USA (1975), Emmenspitz, Switzerland (1976), Moncada, Spain (1975).

The only plant with some reservations about the quality of this boiler design is Saugus whereas the boiler unit number 1 at Landshut in the meanwhile is in operation fro approx. 51'000 hrs. without the need of a mechanical cleaning. We would like to draw your attention to that subject on a paper given at the CRE Conference in Montreux in 1975.

The adaption of this boiler type by W"E for Hamburg-Stapelfeld can simply be considered as a copy done by former Von Roll employees.

Finally, we would like to mention, that in the list of worldwide inventory of waste-to-energy systems we are missing some Von Roll plants. We are airmailing you today one newest reference list. Please note also, that the Volund Company did not participate at the delivery of the Nyborg Plant in Denmark.

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